

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/04174

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁷ G02B6/12, H05K1/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl⁷ G02B6/12-6/14, G02B6/42-6/43, H05K1/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2000
Kokai Jitsuyo Shinan Koho 1971-2000 Jitsuyo Shinan Toroku Koho 1996-2000

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, 9-281352, A (Fuji Xerox Co., Ltd.), 31 October, 1997 (31.10.97) (Family: none)	1, 6, 8, 10-12
Y		2-5, 7, 9, 13
A		14-16
Y	JP, 5-264833, A (Hitachi Maxell, Ltd.), 15 October, 1993 (15.10.93) (Family: none)	2-5, 7, 9, 13
A		14-16
Y	JP, 61-500941, A (Hase, Klaus-Rüdiger, Dr.), 08 May, 1986 (08.05.86), Figs. 6c, 7b & EP, 0168444, A & WO, 8503179, A1	2-5, 7, 9, 13
A		14-16
Y	JP, 10-126018, A (Advantest Corporation), 15 May, 1998 (15.05.98), Par. No. [0012] & WO, 9818301, A1	9

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
18 September, 2000 (18.09.00)

Date of mailing of the international search report
03 October, 2000 (03.10.00)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

P C T

国際調査報告

(法 8 条、法施行規則第40、41条)
〔P C T 1 8 条、P C T 規則43、44〕

出願人又は代理人 の書類記号 0 0 S 0 6 7 4 P	今後の手続きについては、国際調査報告の送付通知様式(P C T / I S A / 2 2 0) 及び下記 5 を参照すること。	
国際出願番号 P C T / J P 0 0 / 0 4 1 7 4	国際出願日 (日.月.年) 2 6 . 0 6 . 0 0	優先日 (日.月.年) 2 5 . 0 6 . 9 9
出願人 (氏名又は名称) 凸版印刷株式会社		

国際調査機関が作成したこの国際調査報告を法施行規則第41条 (P C T 1 8 条) の規定に従い出願人に送付する。
この写しは国際事務局にも送付される。

この国際調査報告は、全部で 3 ページである。

☐ この調査報告に引用された先行技術文献の写しも添付されている。

1. 国際調査報告の基礎

a. 言語は、下記に示す場合を除くほか、この国際出願がされたものに基づき国際調査を行った。

☐ この国際調査機関に提出された国際出願の翻訳文に基づき国際調査を行った。

b. この国際出願は、ヌクレオチド又はアミノ酸配列を含んでおり、次の配列表に基づき国際調査を行った。

☐ この国際出願に含まれる書面による配列表

☐ この国際出願と共に提出されたフレキシブルディスクによる配列表

☐ 出願後に、この国際調査機関に提出された書面による配列表

☐ 出願後に、この国際調査機関に提出されたフレキシブルディスクによる配列表

☐ 出願後に提出した書面による配列表が出願時における国際出願の開示の範囲を超える事項を含まない旨の陳述書の提出があった。

☐ 書面による配列表に記載した配列とフレキシブルディスクによる配列表に記録した配列が同一である旨の陳述書の提出があった。

2. ☐ 請求の範囲の一部の調査ができない (第 I 欄参照)。

3. ☐ 発明の単一性が欠如している (第 II 欄参照)。

4. 発明の名称は ☒ 出願人が提出したものを承認する。

☐ 次に示すように国際調査機関が作成した。

5. 要約は ☒ 出願人が提出したものを承認する。

☐ 第 III 欄に示されているように、法施行規則第47条 (P C T 規則38.2(b)) の規定により国際調査機関が作成した。出願人は、この国際調査報告の発送の日から 1 カ月以内にこの国際調査機関に意見を提出することができる。

6. 要約書とともに公表される図は、

第 3 図とする。 ☒ 出願人が示したとおりである。

☐ なし

☐ 出願人は図を示さなかった。

☐ 本図は発明の特徴を一層よく表している。

A. 発明の属する分野の分類 (国際特許分類 (IPC))

Int. Cl⁷ G02B6/12, H05K1/02

B. 調査を行った分野

調査を行った最小限資料 (国際特許分類 (IPC))

Int. Cl⁷ G02B6/12-6/14, G02B6/42-6/43, H05K1/02

最小限資料以外の資料で調査を行った分野に含まれるもの

日本国実用新案公報	1922-1996年
日本国公開実用新案公報	1971-2000年
日本国登録実用新案公報	1994-2000年
日本国実用新案登録公報	1996-2000年

国際調査で使用した電子データベース (データベースの名称、調査に使用した用語)

C. 関連すると認められる文献

引用文献の カテゴリー*	引用文献名 及び一部の箇所が関連するときは、その関連する箇所の表示	関連する 請求の範囲の番号
X	JP, 9-281352, A (富士ゼロックス株式会社) 31, 10月, 1997 (31. 10. 97) (ファミリーなし)	1, 6, 8, 10-12
Y		2-5, 7, 9, 13
A		14-16

☒ C欄の続きにも文献が列挙されている。☐ パテントファミリーに関する別紙を参照。

* 引用文献のカテゴリー

「A」特に関連のある文献ではなく、一般的技術水準を示すもの
「E」国際出願日前の出願または特許であるが、国際出願日以後に公表されたもの
「L」優先権主張に疑義を提起する文献又は他の文献の発行日若しくは他の特別な理由を確立するために引用する文献 (理由を付す)
「O」口頭による開示、使用、展示等に言及する文献
「P」国際出願日前で、かつ優先権の主張の基礎となる出願

の日の後に公表された文献
「T」国際出願日又は優先日後に公表された文献であって出願と矛盾するものではなく、発明の原理又は理論の理解のために引用するもの
「X」特に関連のある文献であって、当該文献のみで発明の新規性又は進歩性がないと考えられるもの
「Y」特に関連のある文献であって、当該文献と他の1以上の文献との、当業者にとって自明である組合せによって進歩性がないと考えられるもの
「&」同一パテントファミリー文献

国際調査を完了した日

18. 09. 00

国際調査報告の発送日

03.10.00

国際調査機関の名称及びあて先

日本国特許庁 (ISA/JP)
郵便番号 100-8915
東京都千代田区霞が関三丁目4番3号

特許庁審査官 (権限のある職員)

岡田 吉美



2K

9315

電話番号 03-3581-1101 内線 3253

C (続き). 関連すると認められる文献		
引用文献の カテゴリー*	引用文献名 及び一部の箇所が関連するときは、その関連する箇所の表示	関連する 請求の範囲の番号
Y	JP, 5-264833, A (日立マクセル株式会社) 15, 10 月, 1993 (15. 10. 93) (ファミリーなし)	2-5, 7, 9, 13
A		14-16
Y	JP, 61-500941, A (ハーゼ、クラウスール、ディガ ー) 8, 5月, 1986 (08. 05. 86) 図6c、図7b & EP, 0168444, A & WO, 8503179, A1	2-5, 7, 9, 13
A		14-16
Y	JP, 10-126018, A (株式会社アドバンテスト) 15, 5月, 1998 (15. 05. 98) 段落【0012】 & WO, 9818301, A1	9

(19) 世界知的所有権機関
国際事務局



(43) 国際公開日
2001 年 1 月 4 日 (04.01.2001)

PCT

(10) 国際公開番号
WO 01/01176 A1

(51) 国際特許分類: G02B 6/12, H05K 1/02

(21) 国際出願番号: PCT/JP00/04174

(22) 国際出願日: 2000 年 6 月 26 日 (26.06.2000)

(25) 国際出願の言語: 日本語

(26) 国際公開の言語: 日本語

(30) 優先権データ:
特願平11/179646 1999 年 6 月 25 日 (25.06.1999) JP

(71) 出願人 (米国を除く全ての指定国について): 凸版印刷株式会社 (TOPPAN PRINTING CO., LTD.) [JP/JP]; 〒110-0016 東京都台東区台東一丁目5番1号 Tokyo (JP).

(72) 発明者; および

(75) 発明者/出願人 (米国についてのみ): 塚本 健

人 (TSUKAMOTO, Takehito) [JP/JP]. 吉田 政吉 (YOSHIDA, Masakichi) [JP/JP]. 湊 孝夫 (MINATO, Takao) [JP/JP]; 〒110-0016 東京都台東区台東一丁目5番1号 凸版印刷株式会社内 Tokyo (JP).

(74) 代理人: 鈴江武彦, 外 (SUZUYE, Takehiko et al.); 〒100-0013 東京都千代田区霞が関3丁目7番2号 鈴栄内外国特許法律事務所内 Tokyo (JP).

(81) 指定国 (国内): CA, JP, KR, US.

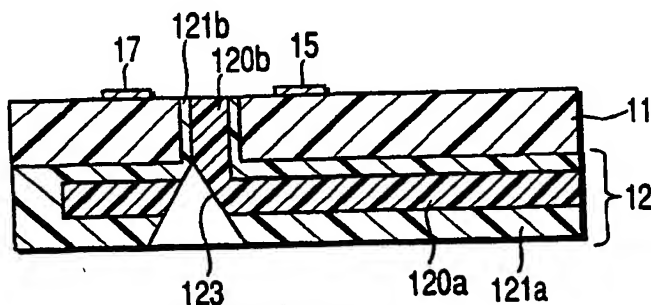
(84) 指定国 (広域): ヨーロッパ特許 (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

添付公開書類:
— 国際調査報告書

2文字コード及び他の略語については、定期発行される各PCTガゼットの巻頭に掲載されている「コードと略語のガイダンスノート」を参照。

(54) Title: PHOTOELECTRIC WIRING BOARD, PACKAGING BOARD, AND PHOTOELECTRIC WIRING BOARD PRODUCING METHOD

(54) 発明の名称: 光・電気配線基板、実装基板及び光電気配線基板の製造方法



(57) Abstract: A photoelectric wiring board (10) which comprises a board (11) formed with a through-hole, and a photo-wiring layer (12) consisting of a core (120) laminated to the board (11) for transmission of light and a clad (121) holding the core (120), wherein the electric wiring board (11) has an electric wiring formed on one surface, and pads (15, 17) electrically connected to the electric wiring and disposed around the through-hole in one surface to install photo-parts, the core (120) having a horizontal waveguide (120a) for horizontal propagation of light along the electric wiring board (11), and a vertical waveguide that is a waveguide crossing the horizontal waveguide (120a) and part of

which is disposed in the through-hole to propagate light in a direction normal to the electric wiring board (11).

[続葉有]

WO 01/01176 A1

47
Translation

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 00S0674P	FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/JP00/04174	International filing date (day/month/year) 26 June 2000 (26.06.00)	Priority date (day/month/year) 25 June 1999 (25.06.99)
International Patent Classification (IPC) or national classification and IPC G02B 6/12, H05K 1/02		
Applicant TOPPAN PRINTING CO., LTD.		

<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of <u>5</u> sheets, including this cover sheet.</p> <p><input type="checkbox"/> This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of _____ sheets.</p>	
<p>3. This report contains indications relating to the following items:</p> <p>I <input checked="" type="checkbox"/> Basis of the report</p> <p>II <input type="checkbox"/> Priority</p> <p>III <input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</p> <p>IV <input type="checkbox"/> Lack of unity of invention</p> <p>V <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</p> <p>VI <input type="checkbox"/> Certain documents cited</p> <p>VII <input type="checkbox"/> Certain defects in the international application</p> <p>VIII <input type="checkbox"/> Certain observations on the international application</p>	

Date of submission of the demand 28 November 2000 (28.11.00)	Date of completion of this report 24 April 2001 (24.04.2001)
Name and mailing address of the IPEA/JP	Authorized officer
Facsimile No.	Telephone No.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/JP 00/04174

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-16	YES
	Claims		NO
Inventive step (IS)	Claims	14-16	YES
	Claims	1-13	NO
Industrial applicability (IA)	Claims	1-16	YES
	Claims		NO

2. Citations and explanations

Document 1: JP, 9-281352, A
 Document 2: JP, 5-264833, A
 Document 3: JP, 61-500941, A
 Document 4: JP, 10-126018, A

The following document is newly cited as Document 5:
 Document 5: US, 5835646, A (Fujitsu, Ltd.), 10 November
 1998 (10.11.98)

The inventions described in Claims 1, 6, 8, and 10 to 12 do not involve an inventive step in the light of Documents 1 and 5.

Claims 1, 6, 8, and 10 to 12 differ from the invention disclosed in Document 1, Figure 7, in that the former is an optical wiring layer laminated to an electrical wiring board, while the latter is an electrical wiring layer laminated to an optical wiring board. Upon further consideration, the feature of laminating an optical wiring layer to an electrical wiring board is disclosed in Figures 10 and 11 in Document 5, and application of this method to the opto-electric wiring board disclosed in Document 1 would merely be a design alteration fittingly performed by a person skilled in the art.

The invention described in Claims 2-5, 7, and 13 do not involve an inventive step in the light of Documents 1, 2, 3, and 5.

Claims 2, 3, 4, 7, and 13 differ from the invention disclosed in Document 1, Figure 7, in that the former is provided with a mirror in order to change the direction of the optical waveguide, while in the latter, the waveguide is bent. Upon further consideration, the feature of using a mirror in order to change the direction of an optical waveguide is common knowledge in the art (disclosed, for example, in Documents 2 and 3), and application of this method to the opto-electrical wiring board disclosed in Document 1 would merely be a design alteration fittingly performed by a person skilled in the art.

Using a tapered shape for a waveguide as described in Claim 5 is standard practice in the optical waveguide field, and is merely a design feature fittingly determined by a person skilled in the art.

The invention described in Claim 9 does not involve an inventive step in the light of Documents 1, 2, 3, 4, and 5.

The feature described in Claim 9 is disclosed in Document 4, Figure 5, paragraph [0012].

The inventions described in Claims 14 to 16 involve an inventive step relative to Documents 1, 2, 3, 4, and 5.

Documents 1 to 5 do not mention "a feature having a step that forms a first through-hole in an electrical wiring board; a step that fills said through-hole with a clad; a step that forms an optical wiring layer comprising a first core and a clad that encloses said first core; a step that forms a second through-hole through the center of the first through-hole, said second through-hole having

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

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an inside diameter less than the inside diameter of the aforementioned first through-hole, with the second through-hole penetrating the aforementioned electrical wiring board, the aforementioned first core, and the aforementioned clad that encloses the first core; and a step that fills the aforementioned second through-hole with a second core and forms a waveguide in a direction perpendicular to the aforementioned electrical wiring board."

特 許 協 力 条 約

PCT

国際予備審査報告

(法第12条、法施行規則第56条)
[PCT36条及びPCT規則70]

出願人又は代理人 の書類記号 00S0674P	今後の手続きについては、国際予備審査報告の送付通知(様式PCT/ IPEA/416)を参照すること。	
国際出願番号 PCT/JP00/04174	国際出願日 (日.月.年) 26.06.00	優先日 (日.月.年) 25.06.99
国際特許分類(IPC) Int. Cl ⁷ G02B 6/12, H05K 1/02		
出願人(氏名又は名称) 凸版印刷株式会社		

1. 国際予備審査機関が作成したこの国際予備審査報告を法施行規則第57条(PCT36条)の規定に従い送付する。
2. この国際予備審査報告は、この表紙を含めて全部で 4 ページからなる。
- ☐ この国際予備審査報告には、附属書類、つまり補正されて、この報告の基礎とされた及び/又はこの国際予備審査機関に対して訂正を含む明細書、請求の範囲及び/又は図面も添付されている。
(PCT規則70.16及びPCT実施細則第607号参照)
この附属書類は、全部で _____ ページである。
3. この国際予備審査報告は、次の内容を含む。
- I ☒ 国際予備審査報告の基礎
 - II ☐ 優先権
 - III ☐ 新規性、進歩性又は産業上の利用可能性についての国際予備審査報告の不作成
 - IV ☐ 発明の単一性の欠如
 - V ☒ PCT35条(2)に規定する新規性、進歩性又は産業上の利用可能性についての見解、それを裏付けるための文献及び説明
 - VI ☐ ある種の引用文献
 - VII ☐ 国際出願の不備
 - VIII ☐ 国際出願に対する意見

国際予備審査の請求書を受理した日 28.11.00	国際予備審査報告を作成した日 24.04.01	
名称及びあて先 日本国特許庁(IPEA/JP) 郵便番号100-8915 東京都千代田区霞が関三丁目4番3号	特許庁審査官(権限のある職員) 岡田 吉美	2K 9315
	電話番号 03-3581-1101 内線 3255	

様式PCT/IPEA/409(表紙)(1998年7月)

I. 国際予備審査報告の基礎

1. この国際予備審査報告は下記の出願書類に基づいて作成された。(法第6条(PCT14条)の規定に基づく命令に
応答するために提出された差し替え用紙は、この報告書において「出願時」とし、本報告書には添付しない。
PCT規則70.16, 70.17)

☒ 出願時の国際出願書類

- ☐ 明細書 第 _____ ページ、 出願時に提出されたもの
明細書 第 _____ ページ、 国際予備審査の請求書と共に提出されたもの
明細書 第 _____ ページ、 _____ 付の書簡と共に提出されたもの
- ☐ 請求の範囲 第 _____ 項、 出願時に提出されたもの
請求の範囲 第 _____ 項、 PCT19条の規定に基づき補正されたもの
請求の範囲 第 _____ 項、 国際予備審査の請求書と共に提出されたもの
請求の範囲 第 _____ 項、 _____ 付の書簡と共に提出されたもの
- ☐ 図面 第 _____ ページ/図、 出願時に提出されたもの
図面 第 _____ ページ/図、 国際予備審査の請求書と共に提出されたもの
図面 第 _____ ページ/図、 _____ 付の書簡と共に提出されたもの
- ☐ 明細書の配列表の部分 第 _____ ページ、 出願時に提出されたもの
明細書の配列表の部分 第 _____ ページ、 国際予備審査の請求書と共に提出されたもの
明細書の配列表の部分 第 _____ ページ、 _____ 付の書簡と共に提出されたもの

2. 上記の出願書類の言語は、下記に示す場合を除くほか、この国際出願の言語である。

上記の書類は、下記の言語である _____ 語である。

- ☐ 国際調査のために提出されたPCT規則23.1(b)にいう翻訳文の言語
☐ PCT規則48.3(b)にいう国際公開の言語
☐ 国際予備審査のために提出されたPCT規則55.2または55.3にいう翻訳文の言語

3. この国際出願は、ヌクレオチド又はアミノ酸配列を含んでおり、次の配列表に基づき国際予備審査報告を行った。

- ☐ この国際出願に含まれる書面による配列表
☐ この国際出願と共に提出されたフレキシブルディスクによる配列表
☐ 出願後に、この国際予備審査(または調査)機関に提出された書面による配列表
☐ 出願後に、この国際予備審査(または調査)機関に提出されたフレキシブルディスクによる配列表
☐ 出願後に提出した書面による配列表が出願時における国際出願の開示の範囲を超える事項を含まない旨の陳述書の提出があった
☐ 書面による配列表に記載した配列とフレキシブルディスクによる配列表に記載した配列が同一である旨の陳述書の提出があった。

4. 補正により、下記の書類が削除された。

- ☐ 明細書 第 _____ ページ
☐ 請求の範囲 第 _____ 項
☐ 図面 図面の第 _____ ページ/図

5. ☐ この国際予備審査報告は、補充欄に示したように、補正が出願時における開示の範囲を越えてされたものと認められるので、その補正がされなかったものとして作成した。(PCT規則70.2(c) この補正を含む差し替え用紙は上記1.における判断の際に考慮しなければならず、本報告に添付する。)

V. 新規性、進歩性又は産業上の利用可能性についての法第12条（PCT35条(2)）に定める見解、それを裏付ける文献及び説明

1. 見解

新規性 (N)	請求の範囲	1-16	有
	請求の範囲		無
進歩性 (IS)	請求の範囲	14-16	有
	請求の範囲	1-13	無
産業上の利用可能性 (IA)	請求の範囲	1-16	有
	請求の範囲		無

2. 文献及び説明 (PCT規則70.7)

国際調査報告で引用した文献を下記のように参照する。

文献1: JP, 9-281352, A
 文献2: JP, 5-264833, A
 文献3: JP, 61-500941, A
 文献4: JP, 10-126018, A

また、文献5として新たに下記のものを引用する。

文献5: US, 5835646, A (Fujitsu, Limited.) 10. 11月. 1998 (10. 11. 98)

請求の範囲1、6、8、10-12に記載された発明は、文献1及び文献5より進歩性を有さない。

請求の範囲1、6、8、10-12と文献1の図7に記載のものとを対比すると、前者は、電気配線基板と光配線層を積層しているのに対して、後者は、光配線基板と電気配線層を積層している点で相違する。この点について検討すると、電気配線基板と光配線層を積層する点は、文献5のFig. 10、Fig. 11に記載されており、該手段を文献1に記載の光電気配線基板に採用することは、当業者が適宜なし得る設計変更である。

請求の範囲2-5、7、13に記載された発明は、文献1、文献2、文献3及び文献5より進歩性を有さない。

請求の範囲2、3、4、7、13と文献1の図7に記載のものとを対比すると、前者では、光導波路の方向を変換するためにミラーが具備されているのに対して、後者では導波路が湾曲されている点で相違する。この点について検討すると、光導波路の方向を変換するためにミラーを用いる点は、例えば文献2、3に記載されているように周知のものであり、該手段を文献1に記載の光電気配線基板に採用することは、当業者が適宜なし得る設計変更である。

請求の範囲5に記載の導波路をテーパー形状とすることは、光導波路の分野ではよく用いられる常套手段であり、当業者が適宜設定すべき設計上の事項に過ぎない。

補充欄 (いずれかの欄の大きさが足りない場合に使用すること)

第 V 欄の続き

請求の範囲 9 に記載された発明は、文献 1、文献 2、文献 3、文献 4 及び文献 5 より進歩性を有さない。

請求の範囲 9 に記載の事項は、文献 4 の図 5、段落【0012】に開示されている。

請求の範囲 14-16 に記載された発明は、文献 1、文献 2、文献 3、文献 4 及び文献 5 に対して進歩性を有する。

文献 1～5 には、「電気配線基板に第 1 の貫通孔を形成する工程、該貫通孔をクラッドで満たす工程、第 1 のコアと該第 1 のコアを囲むクラッドからなる光配線層を形成する工程、前記第 1 の貫通孔の内径より小さい内径を有し、前記電気配線基板と前記第 1 のコア及び第 1 のコアを囲む前記クラッドとを貫通する第 2 の貫通孔を前記第 1 の貫通孔の中心部に形成する工程、前記第 2 の貫通孔を第 2 のコアで満たし前記電気配線基板に対して鉛直方向の導波路を形成する工程とを有する点」が、記載されていない。



US005835646A

United States Patent [19]

Yoshimura et al.

[11] **Patent Number:** 5,835,646[45] **Date of Patent:** Nov. 10, 1998

[54] **ACTIVE OPTICAL CIRCUIT SHEET OR ACTIVE OPTICAL CIRCUIT BOARD, ACTIVE OPTICAL CONNECTOR AND OPTICAL MCM, PROCESS FOR FABRICATING OPTICAL WAVEGUIDE, AND DEVICES OBTAINED THEREBY**

[75] **Inventors:** Tetsuzo Yoshimura; Wataru Sotoyama; Takeshi Ishitsuka; Koji Tsukamoto; Shigenori Aoki; Satoshi Tatsuura; Katsusada Motoyoshi; Yasuhiro Yoneda, all of Kawasaki, Japan

[73] **Assignee:** Fujitsu Limited, Kanagawa, Japan

[21] **Appl. No.:** 694,583

[22] **Filed:** Aug. 9, 1996

[30] **Foreign Application Priority Data**

Sep. 19, 1995	[JP]	Japan	7-239782
Sep. 20, 1995	[JP]	Japan	7-241924
Sep. 29, 1995	[JP]	Japan	7-253833

[51] **Int. Cl.⁶** G02B 6/26

[52] **U.S. Cl.** 385/14; 385/134; 385/49; 385/45; 385/88; 385/89; 385/83; 385/24; 385/43; 385/37; 385/28

[58] **Field of Search** 385/14, 88, 89, 385/90, 91, 92, 93, 94, 49, 134, 45, 83, 24, 43, 37, 28

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,521,992	5/1996	Chun et al.	385/14
5,546,489	8/1996	Saski et al.	385/88
5,550,941	8/1996	Lebby et al.	385/49
5,625,734	4/1997	Thomas et al.	385/88

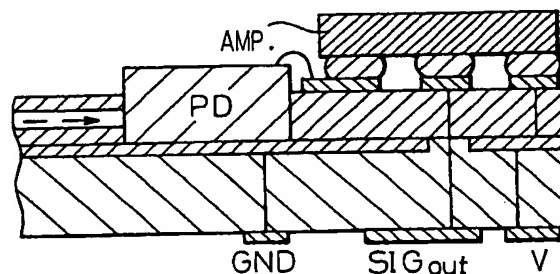
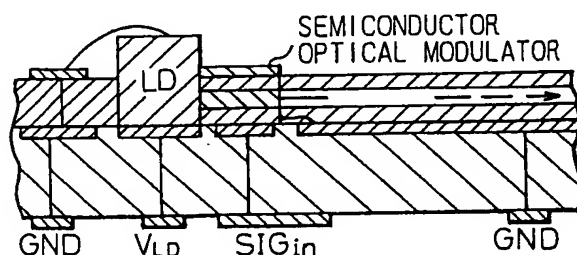
Primary Examiner—John Ngo

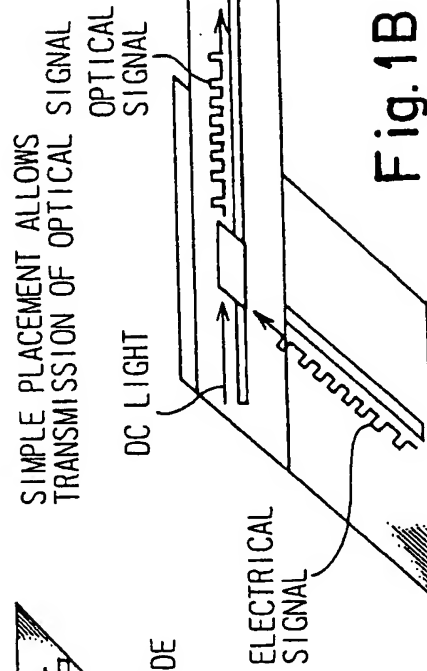
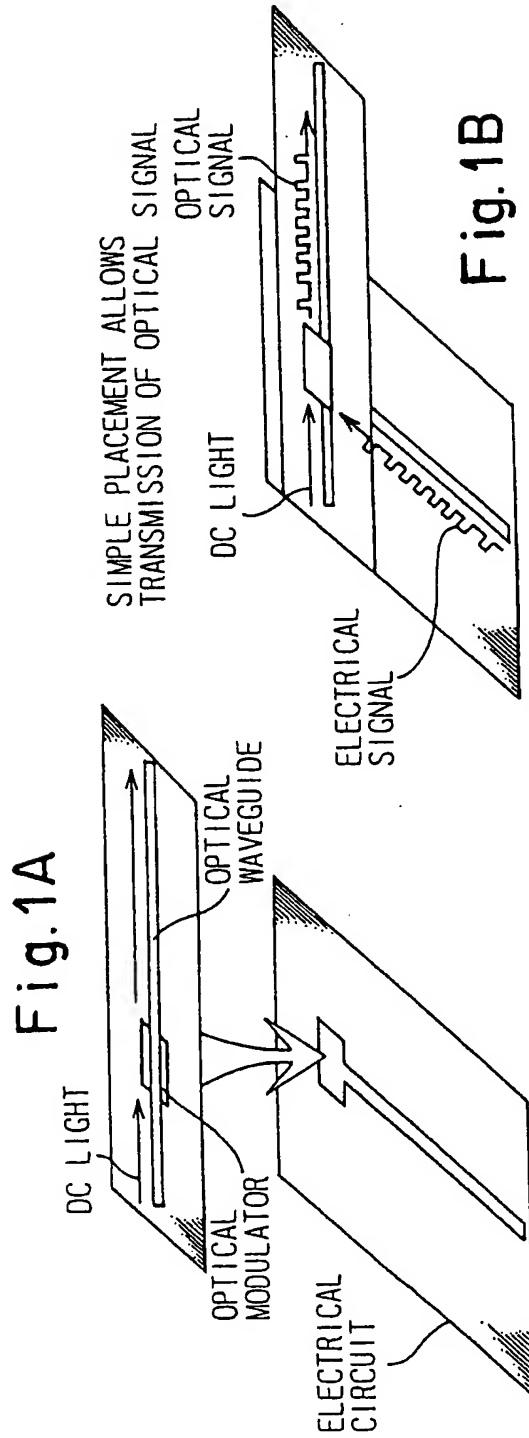
Attorney, Agent, or Firm—Armstrong, Westerman, Hattori, McLeland & Naughton

[57] **ABSTRACT**

An active optical circuit sheet or active optical circuit board wherein an electro optical switch or optical modulator is driven with a voltage (SIGin) from an electronic device, the electrical signal (SIGin) is converted to an optical signal, transmitted and then converted to an electrical signal (SIGout) at an optical receiver element, and an electrical connection is formed between an optical wiring board and the electronic device for transmission of signals to another or the same electronic device, separating the electrical wiring at the electronic device end and the optical wiring at the optical wiring board end, or alternatively, SIGin and SIGout electrode pads are provided on the side of the optical wiring board on which the optical device is mounted or on the opposite side, for connection with the electronic device.

9 Claims, 32 Drawing Sheets





TRANSMITTER

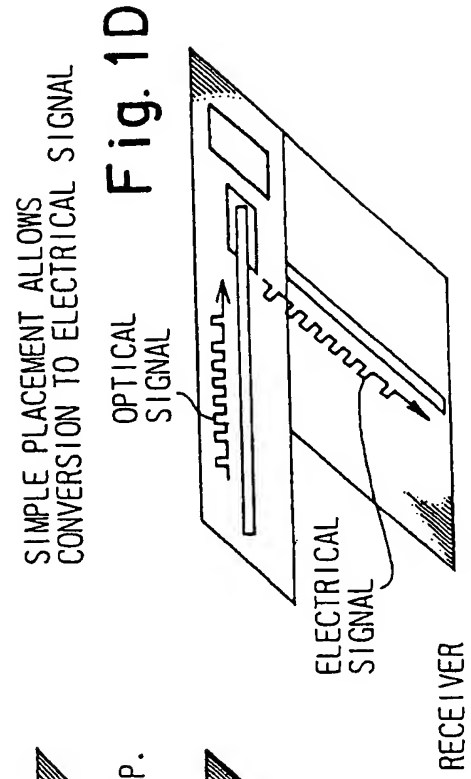
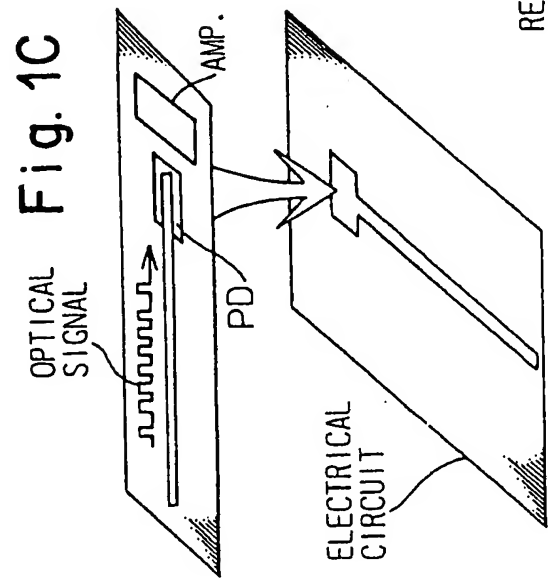
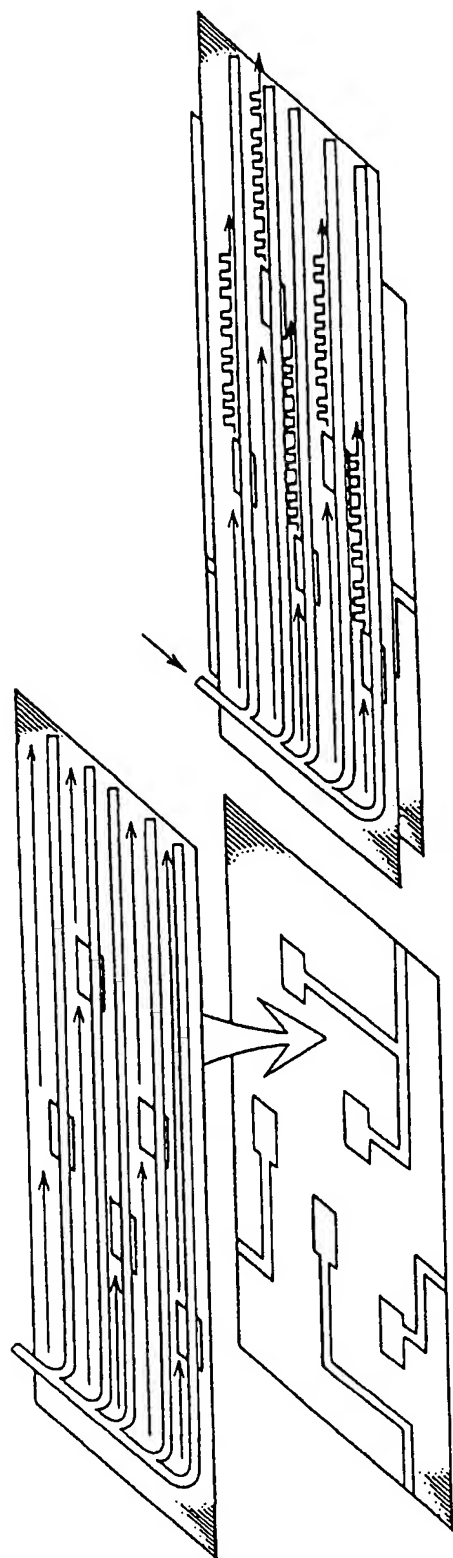
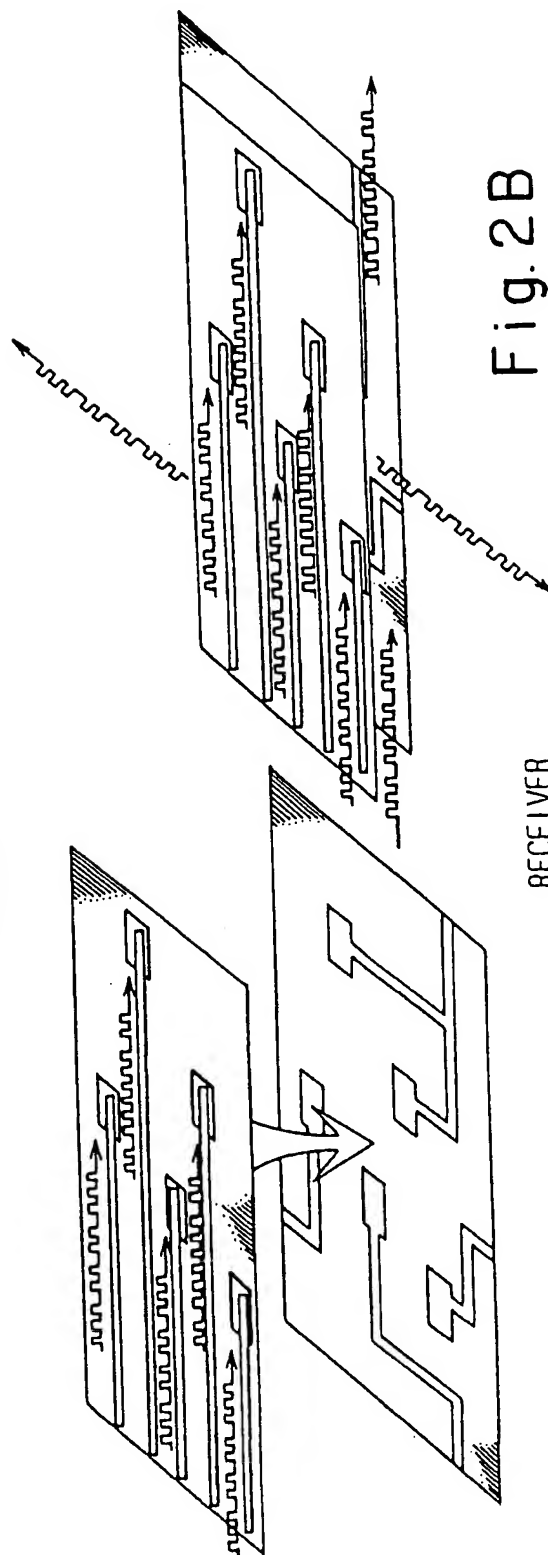


Fig. 2A



TRANSMITTER

Fig. 2B



RECEIVER

Fig.3

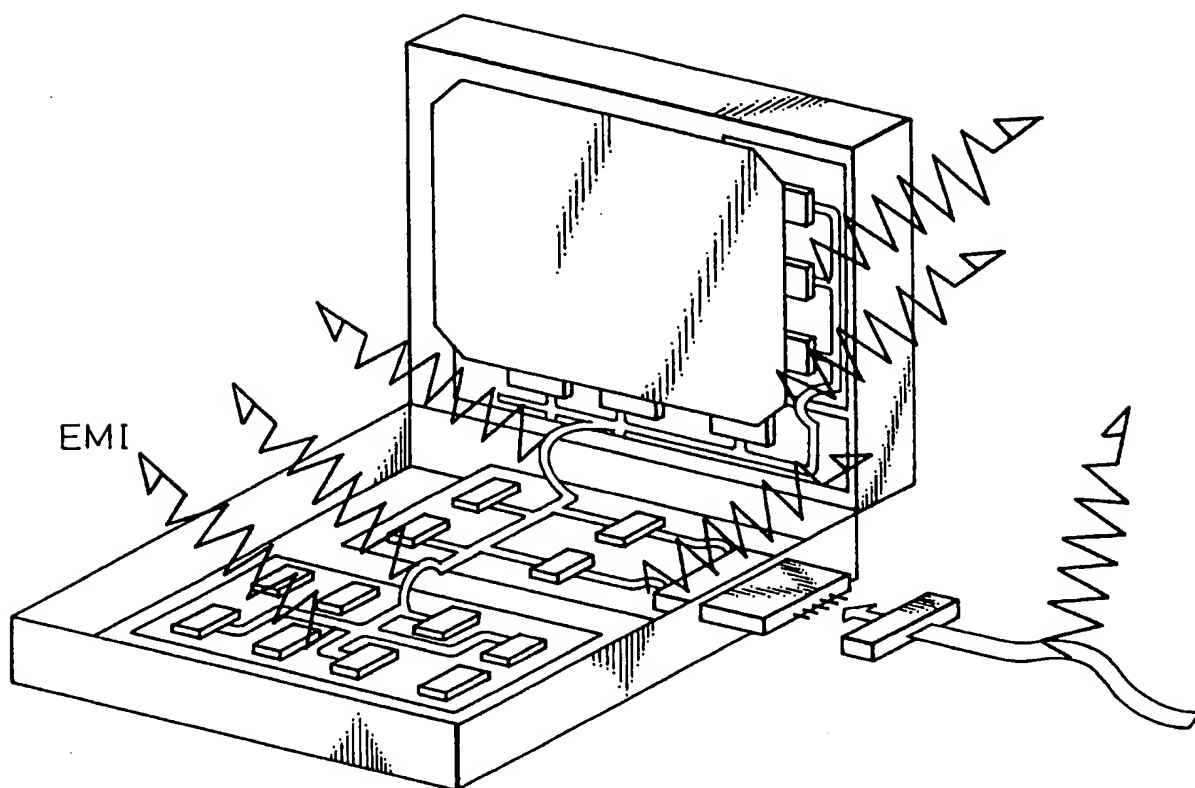


Fig. 4

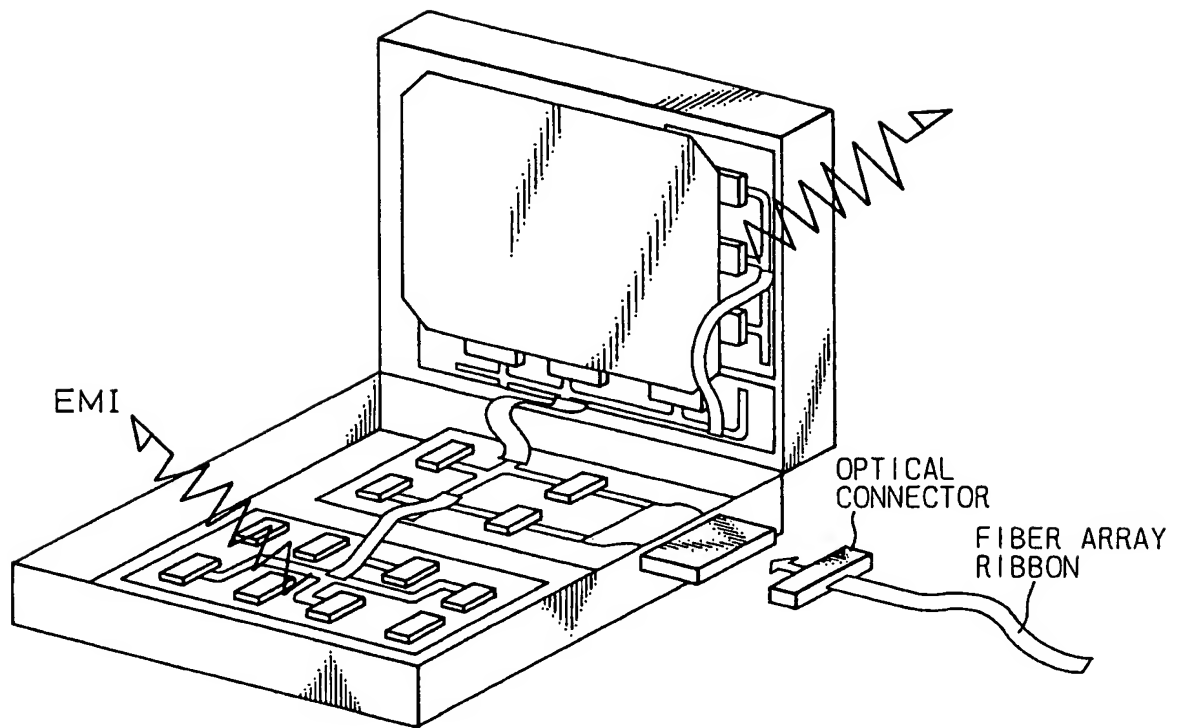
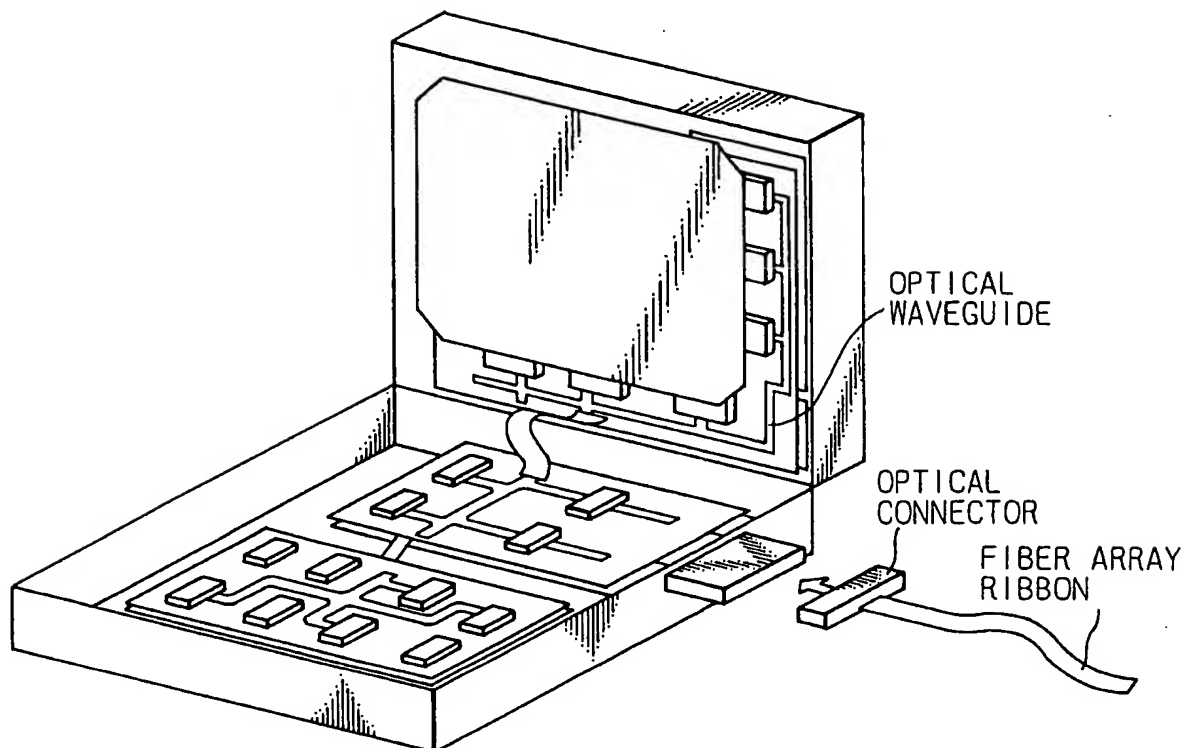
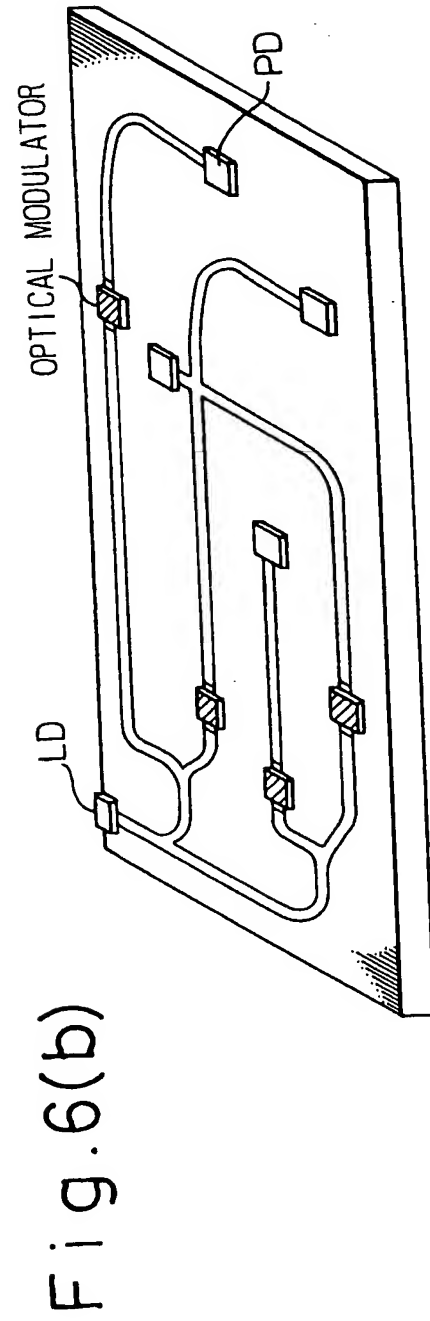
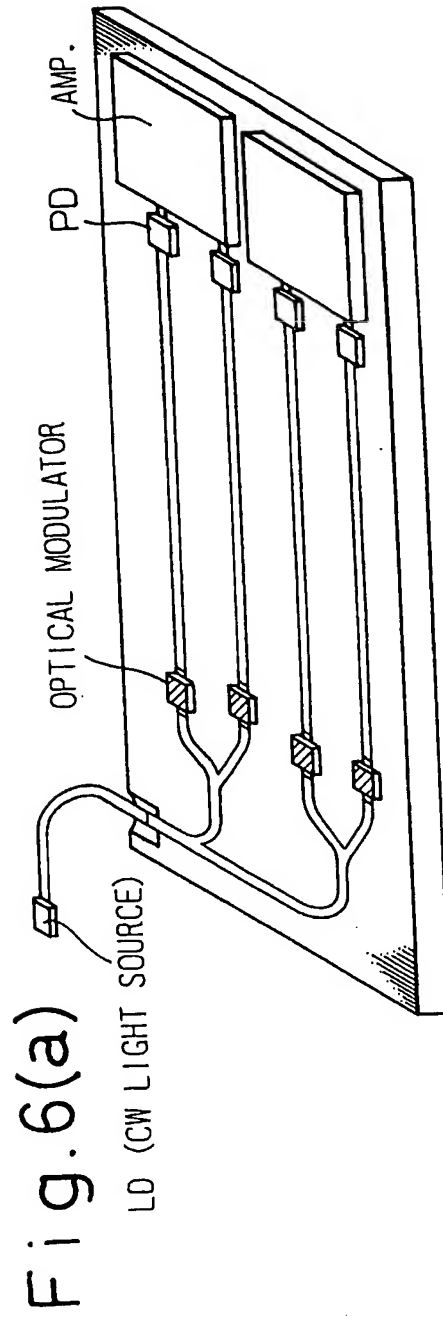
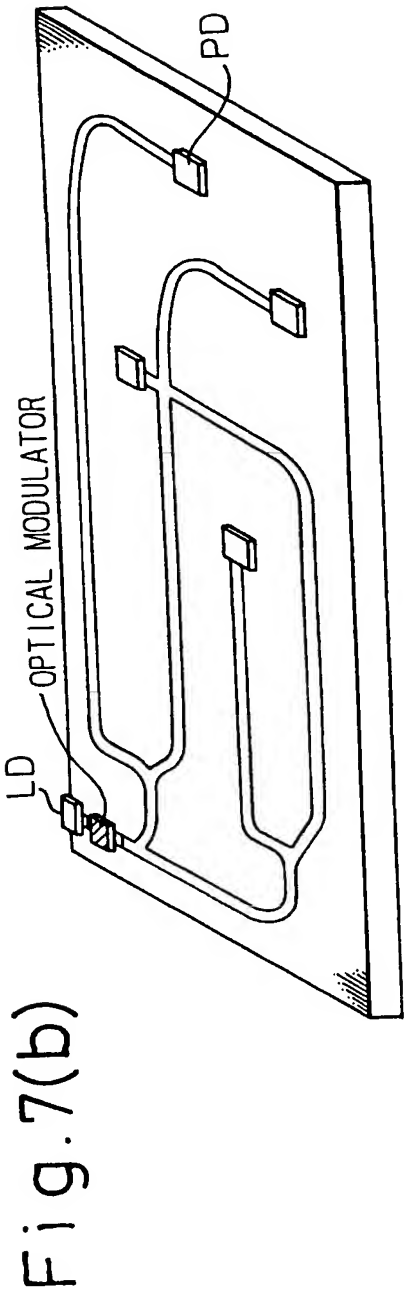
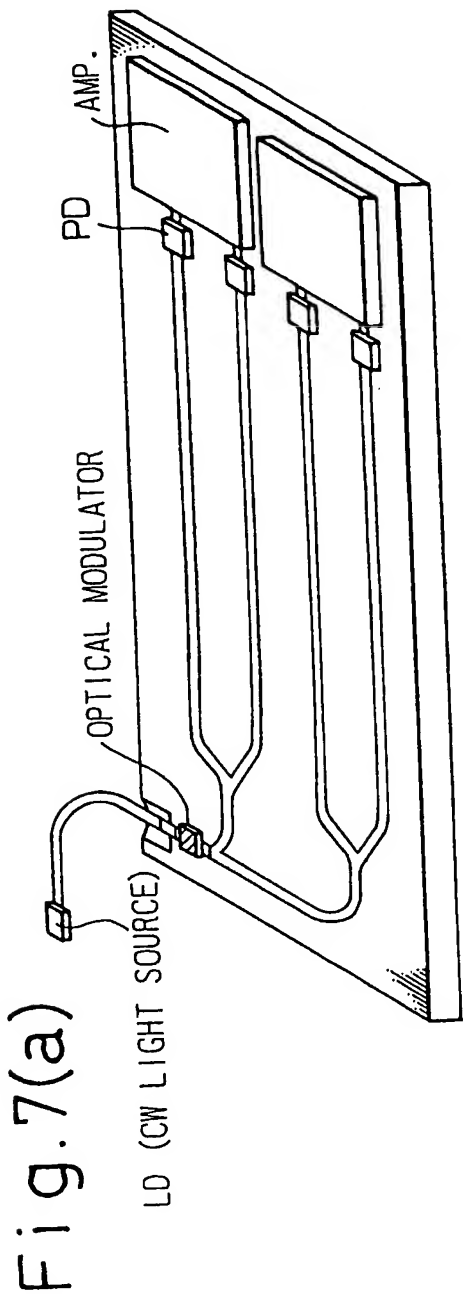


Fig. 5







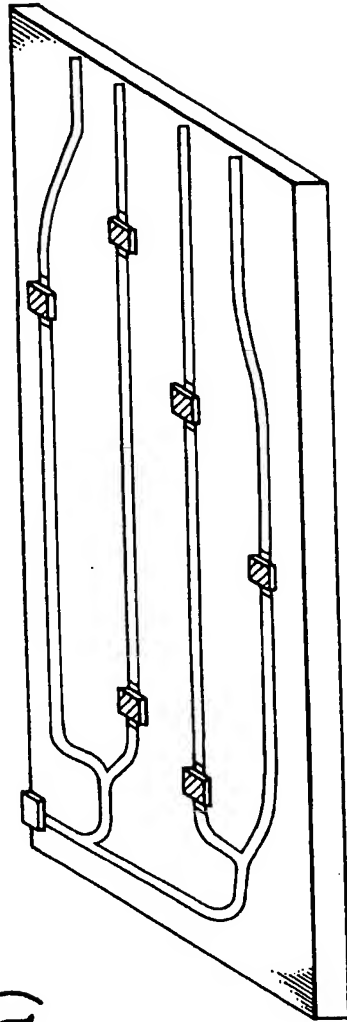


Fig. 8(a)

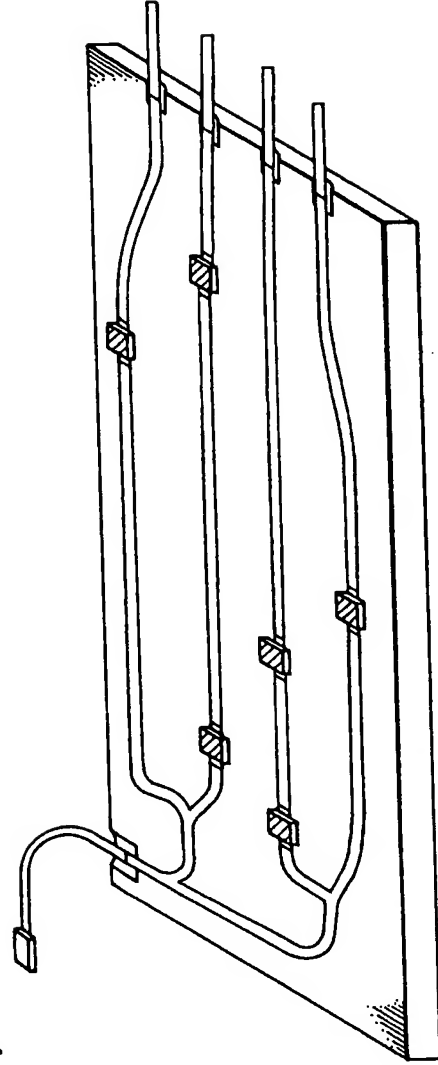


Fig. 8(b)

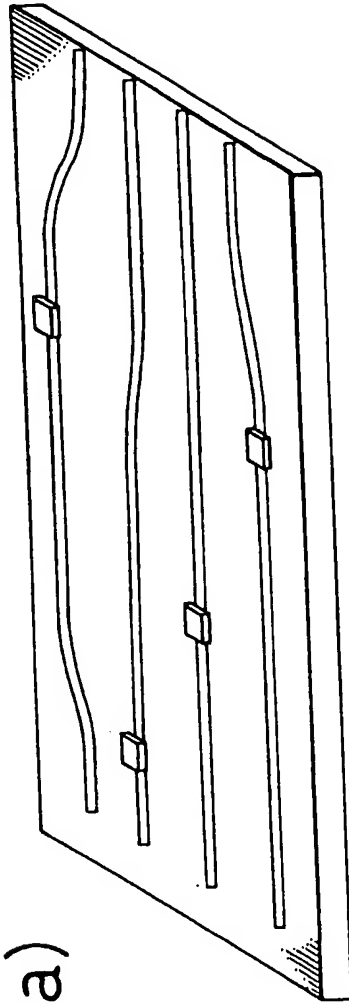


Fig. 9(a)

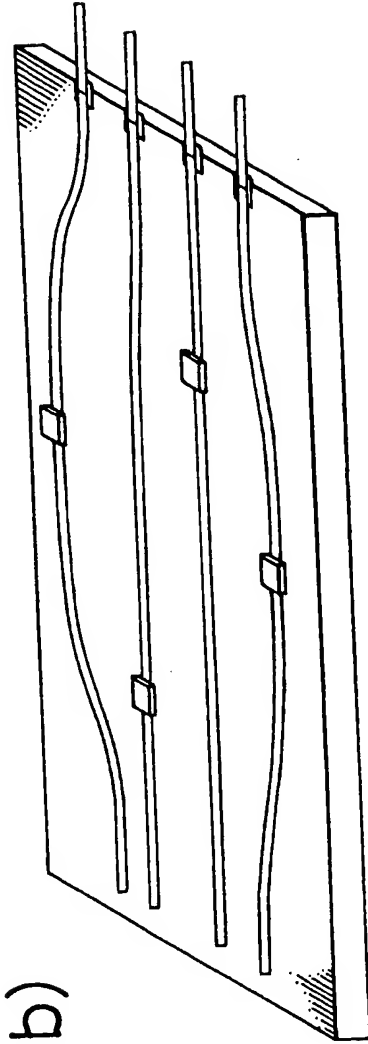


Fig. 9(b)

Fig.10(a)

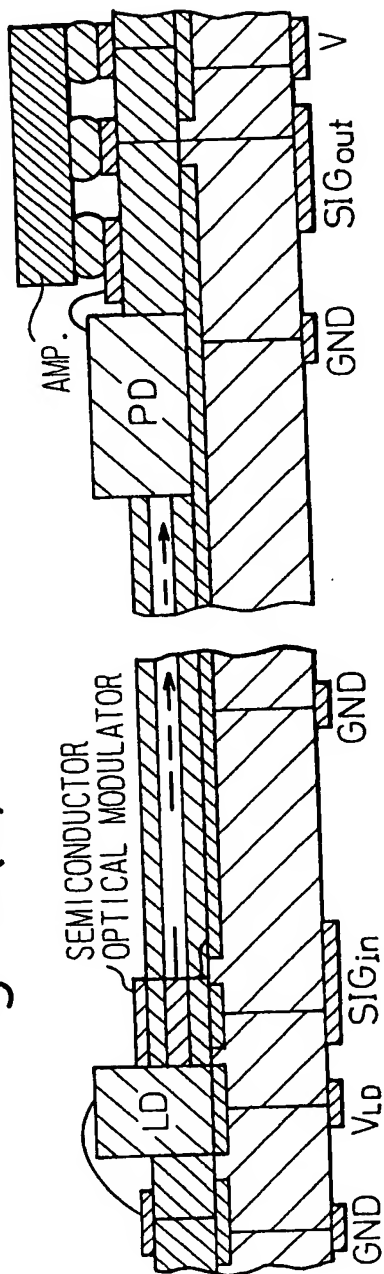


Fig.10(b)

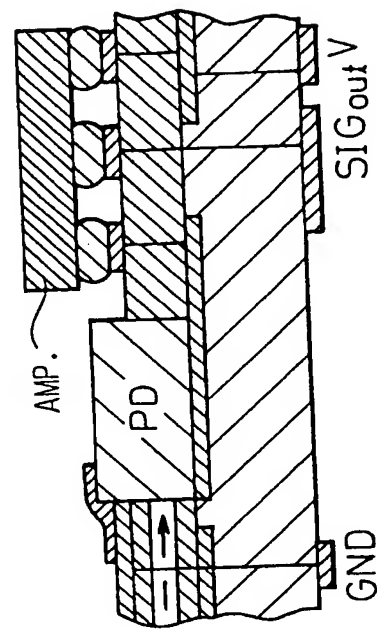


Fig.10(c)

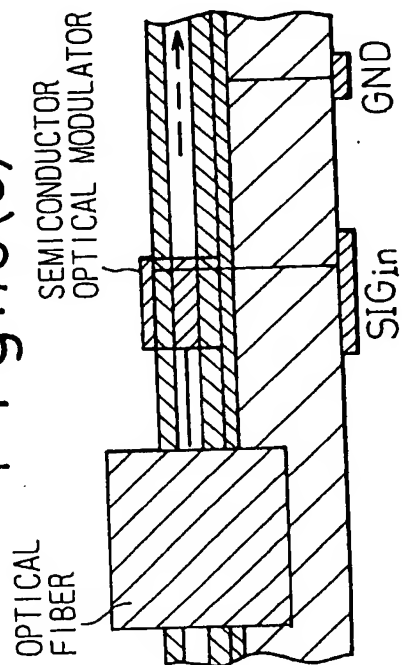
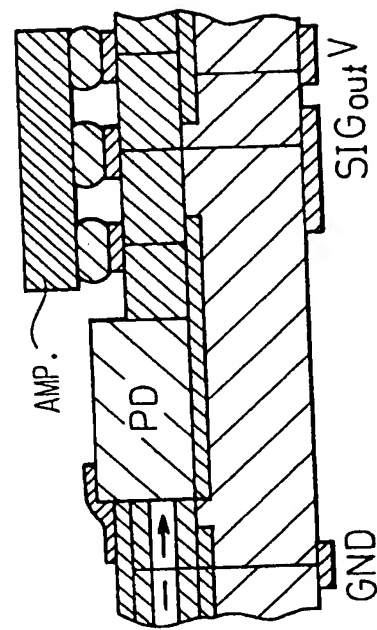


Fig.10(d)



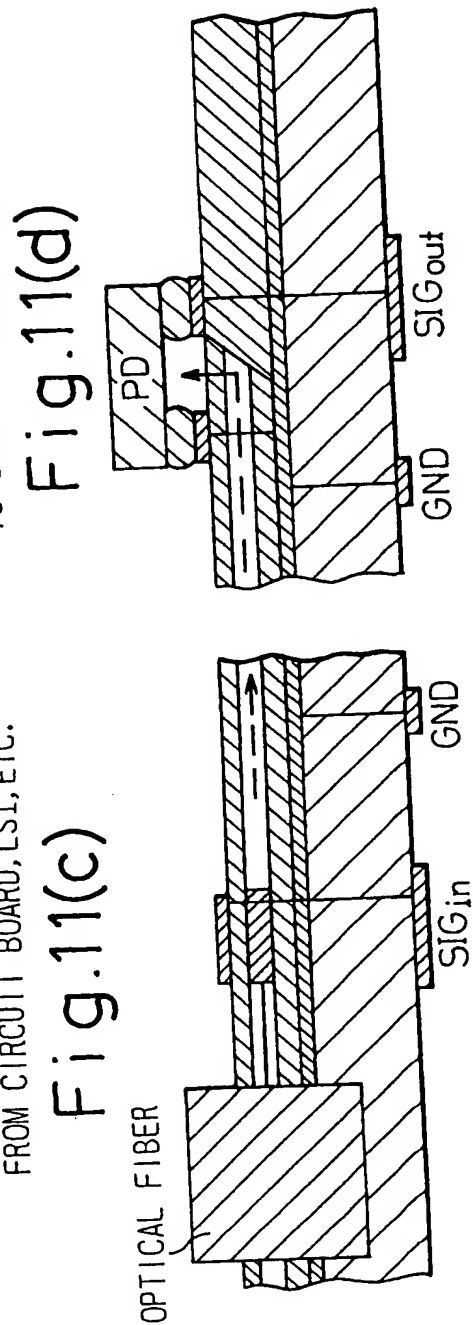
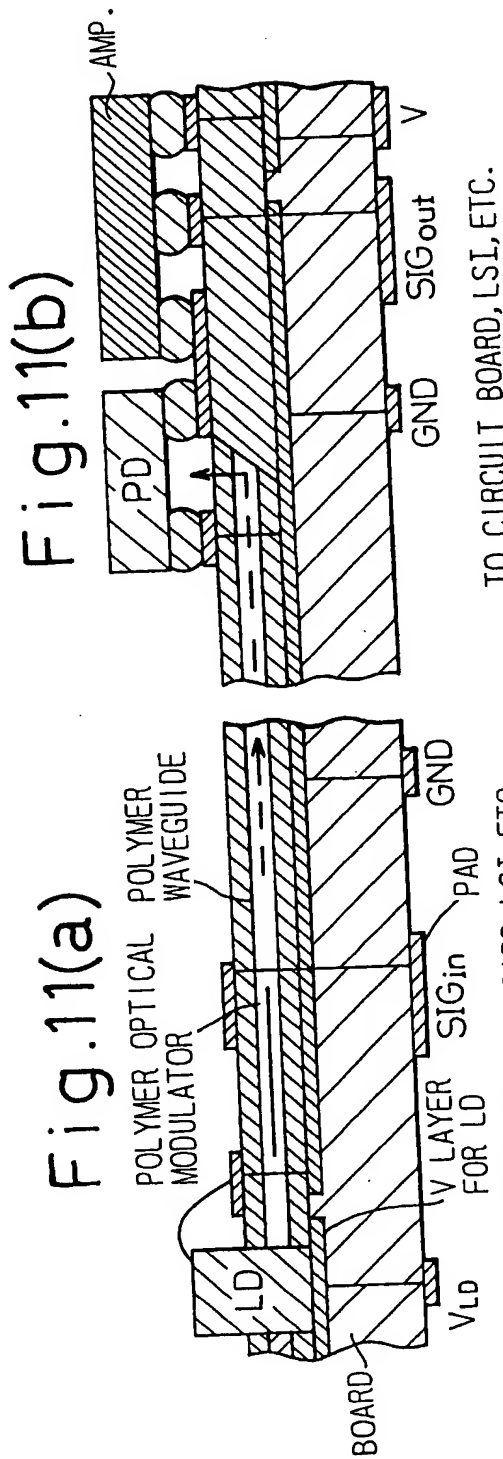


Fig.12

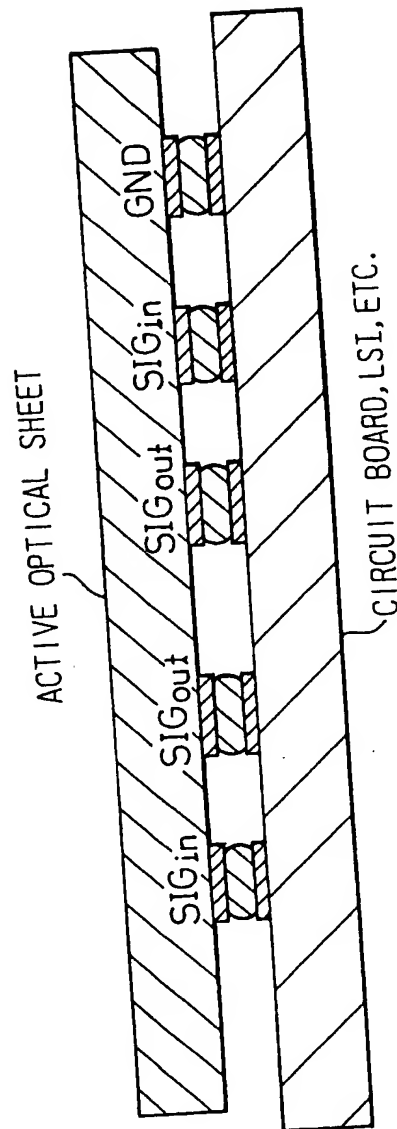


Fig.13A

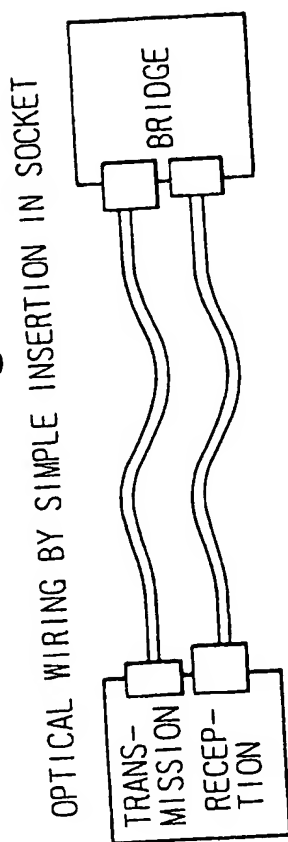


Fig.13C

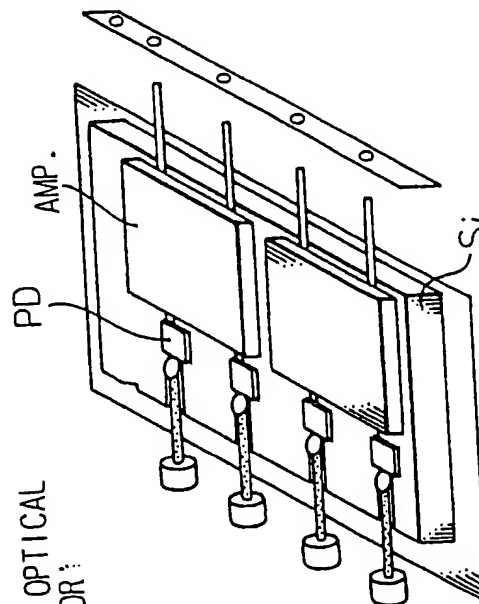


Fig.13B

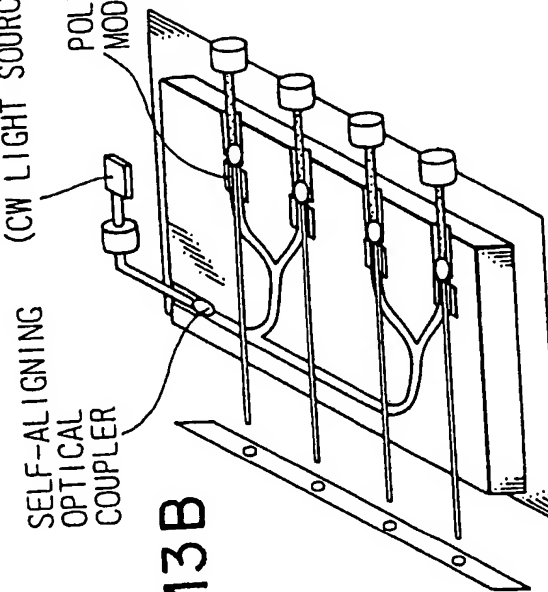


Fig. 14A

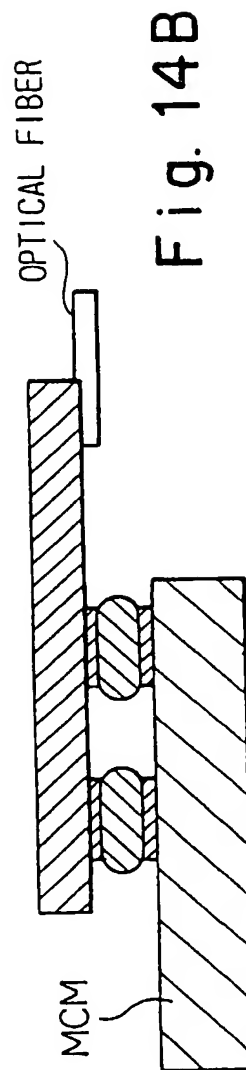
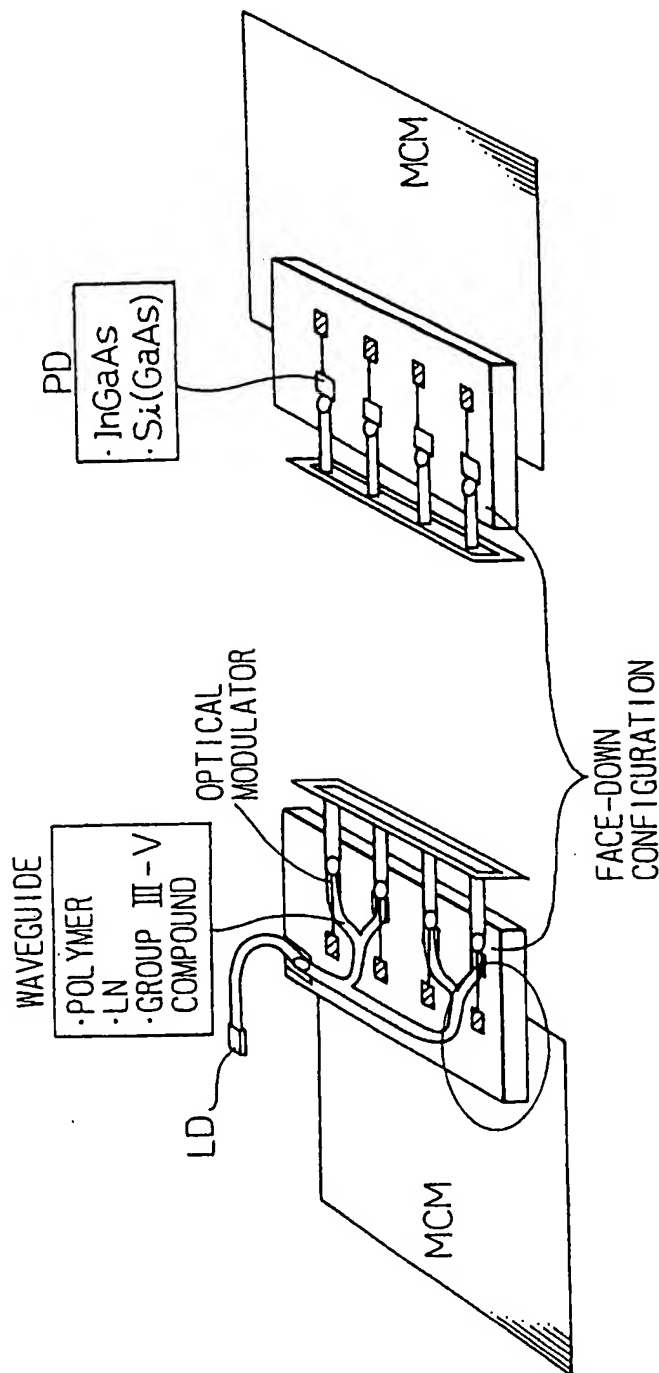


Fig. 15A

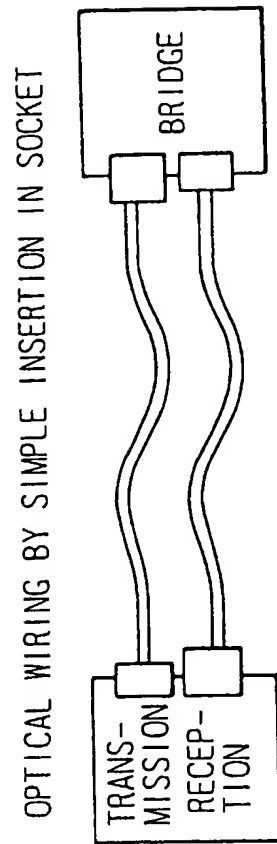


Fig. 15C

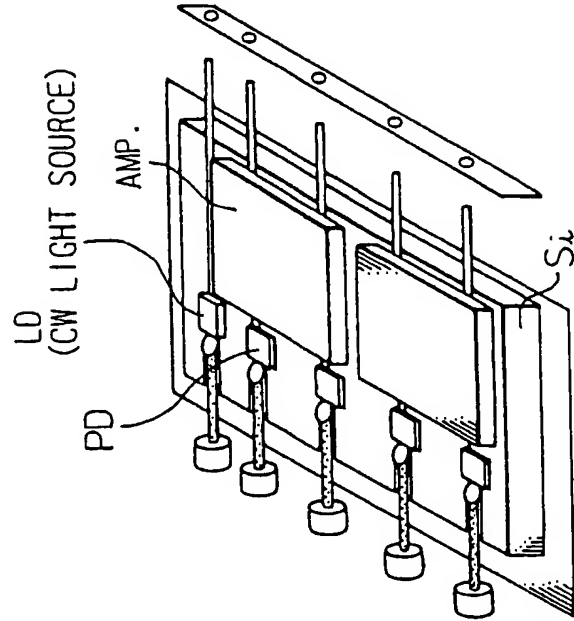


Fig. 15B

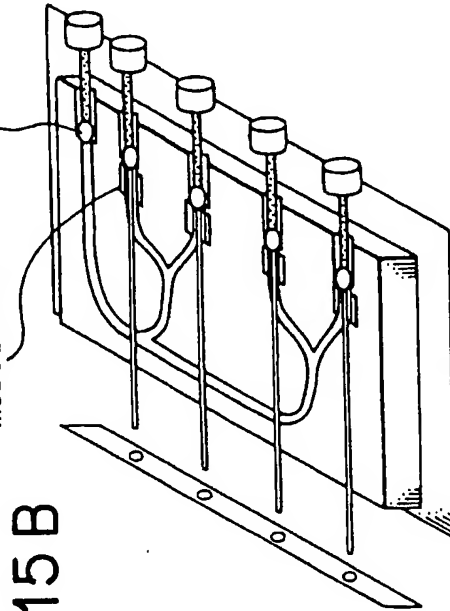


Fig. 16A

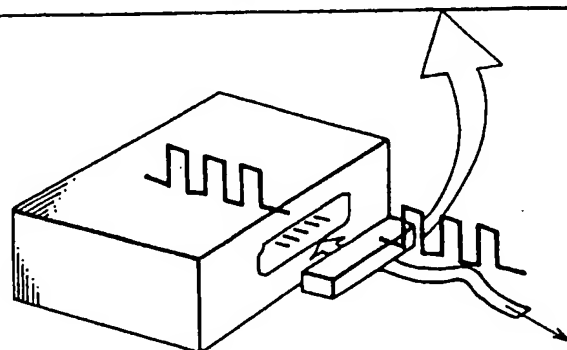
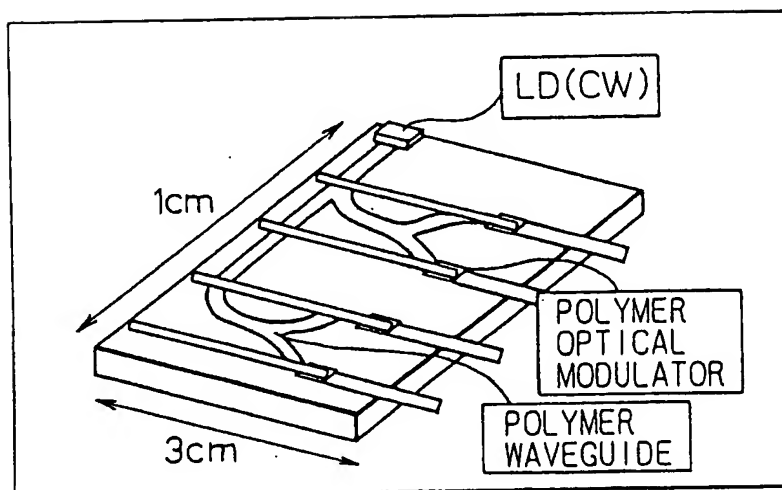


Fig. 16B

Fig.17A

OPTICAL TRANSMISSION BY PLUGGING IN ELECTRICAL CONNECTOR
CLOCK RATE: A FEW 100 MHz

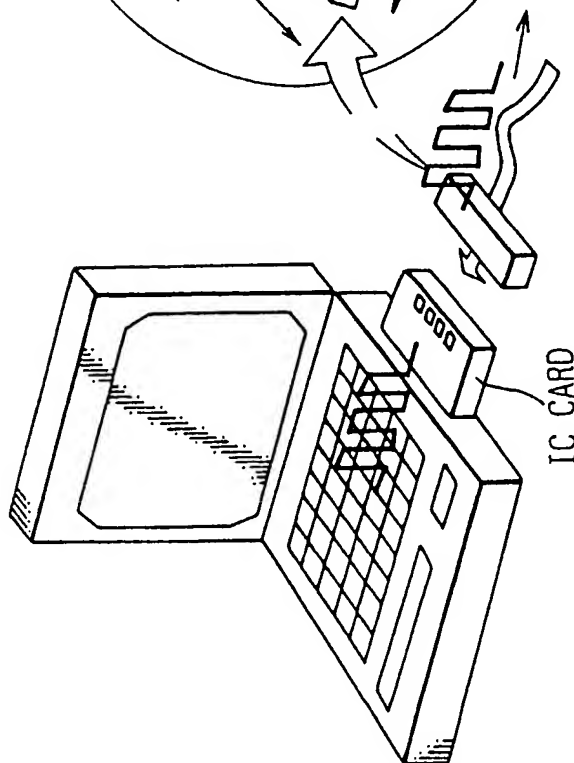


Fig.17B

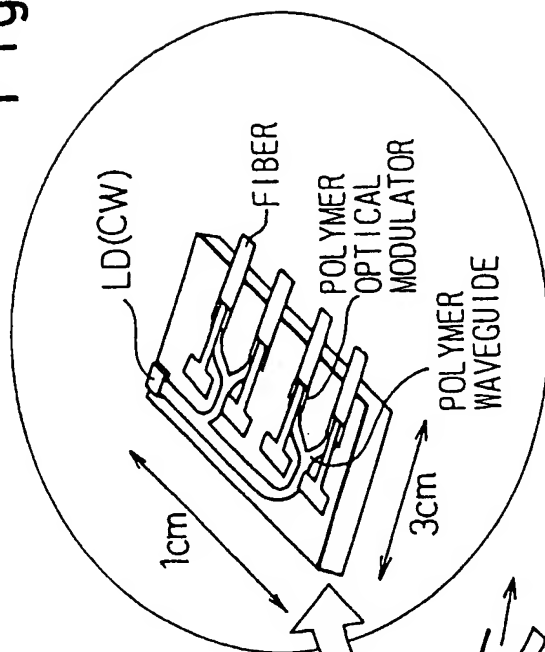


Fig. 18B

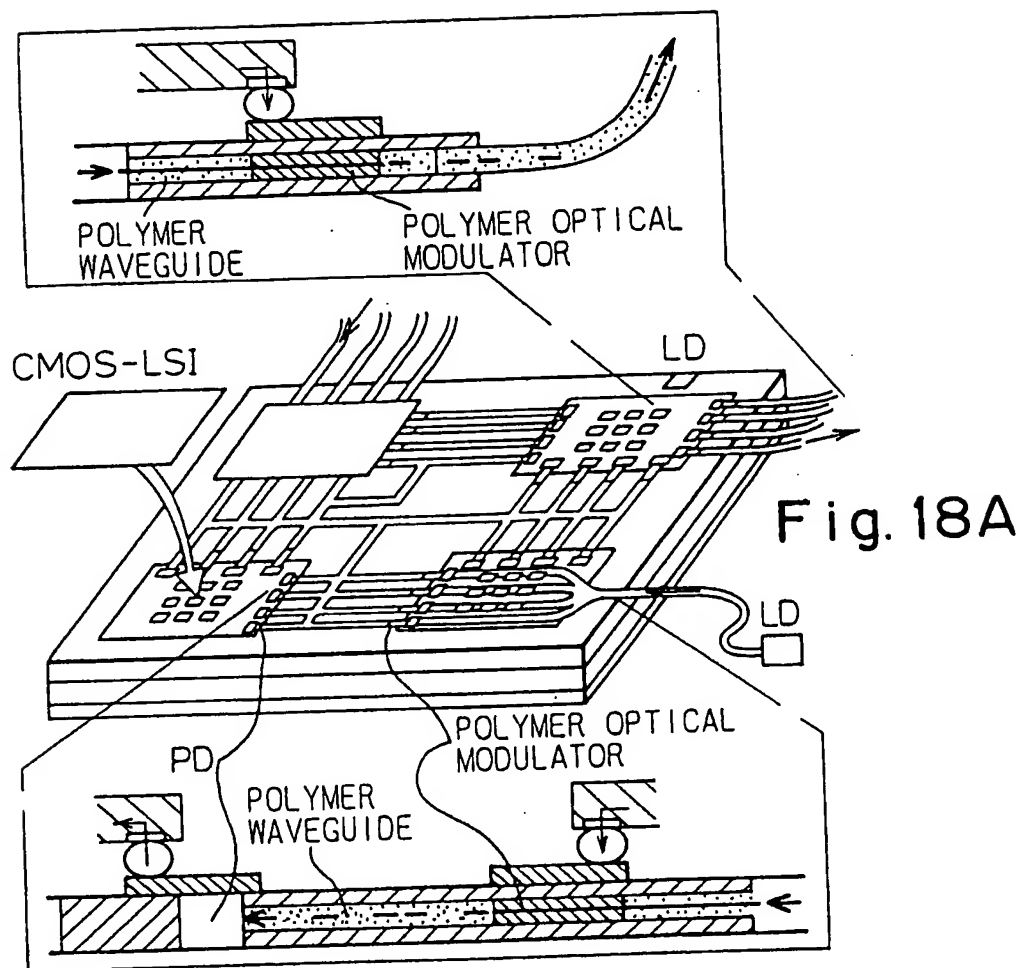


Fig. 18C

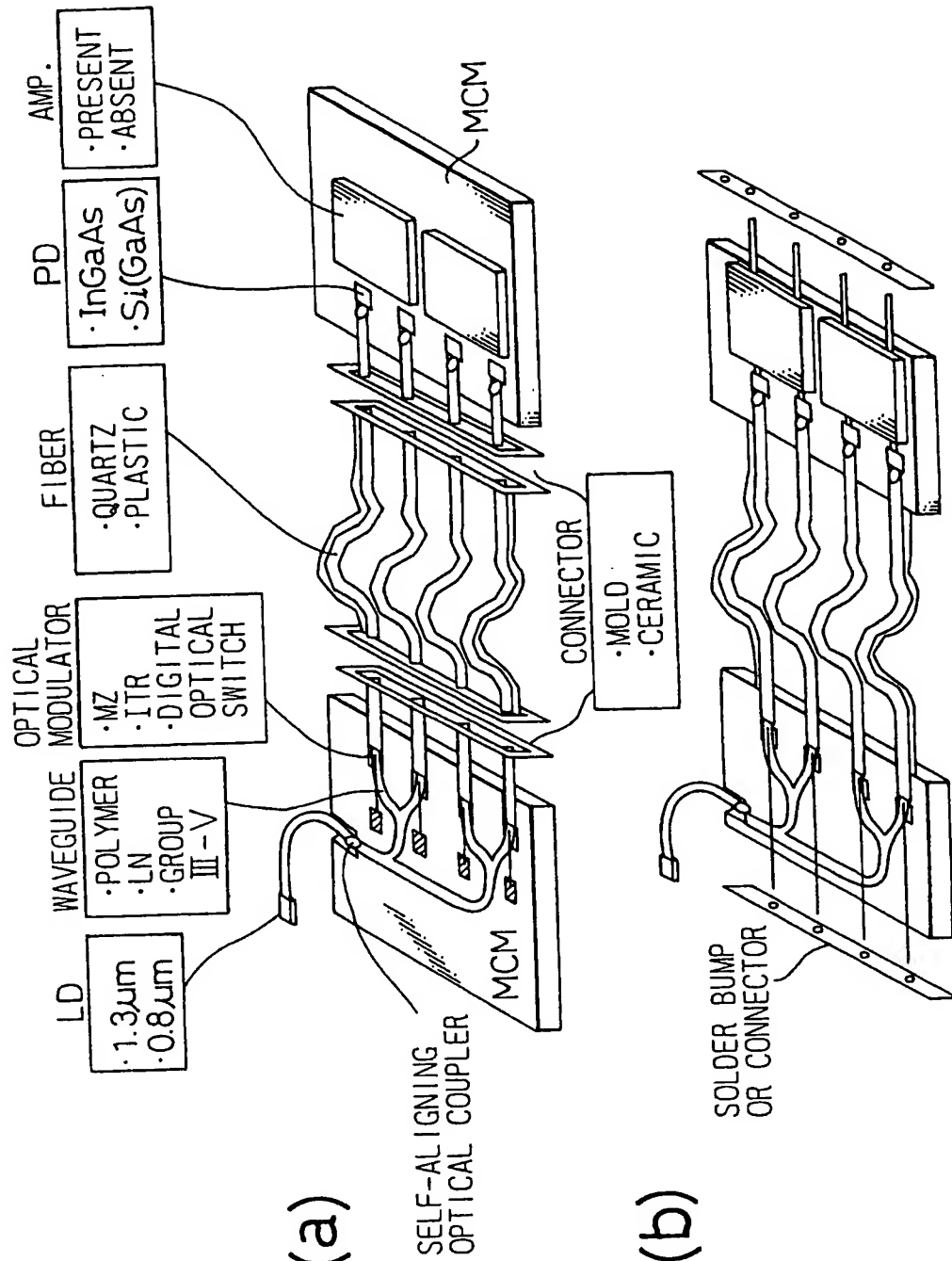


Fig. 19(a)

Fig. 19(b)

Fig. 20

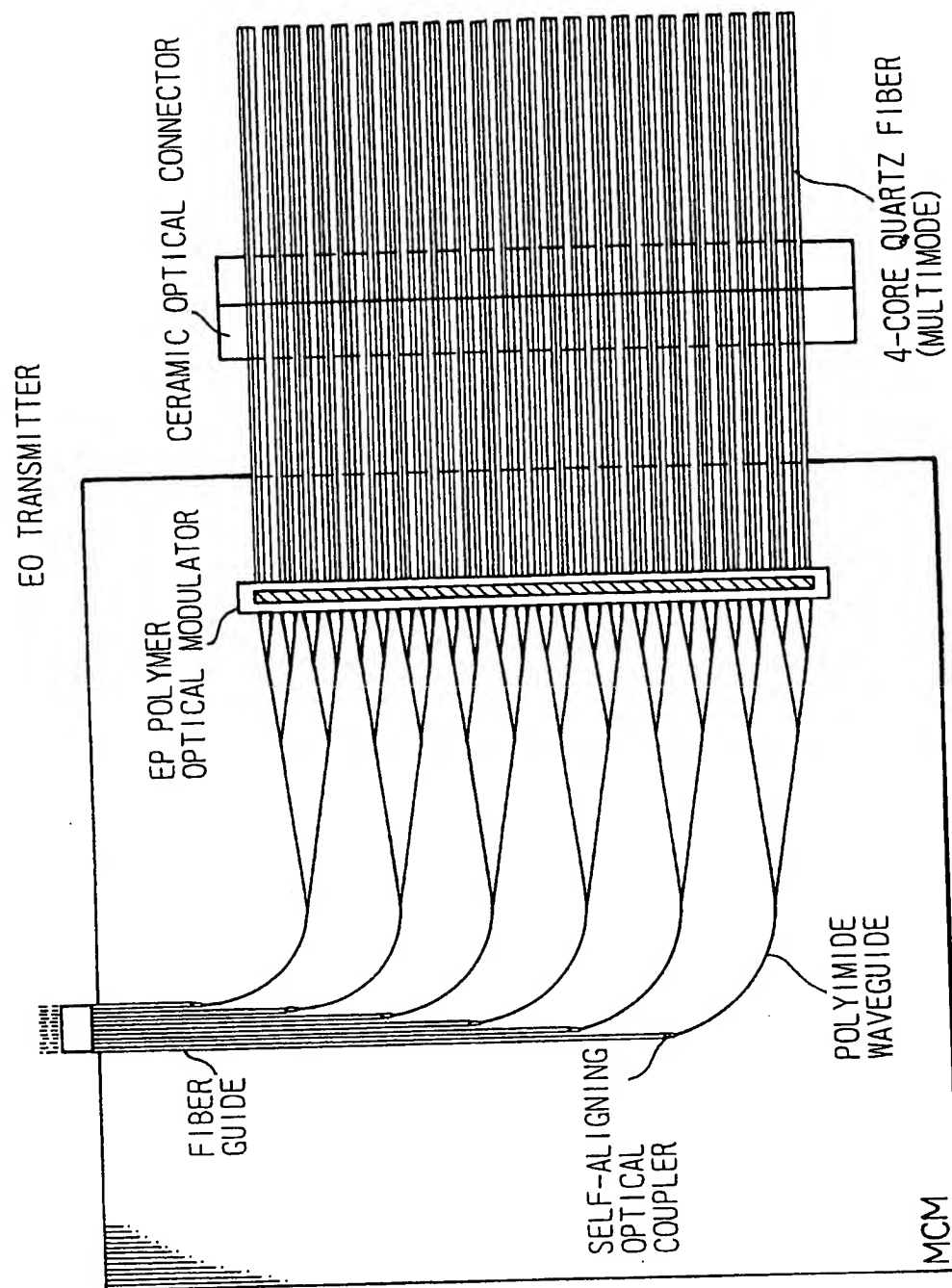


Fig. 21A

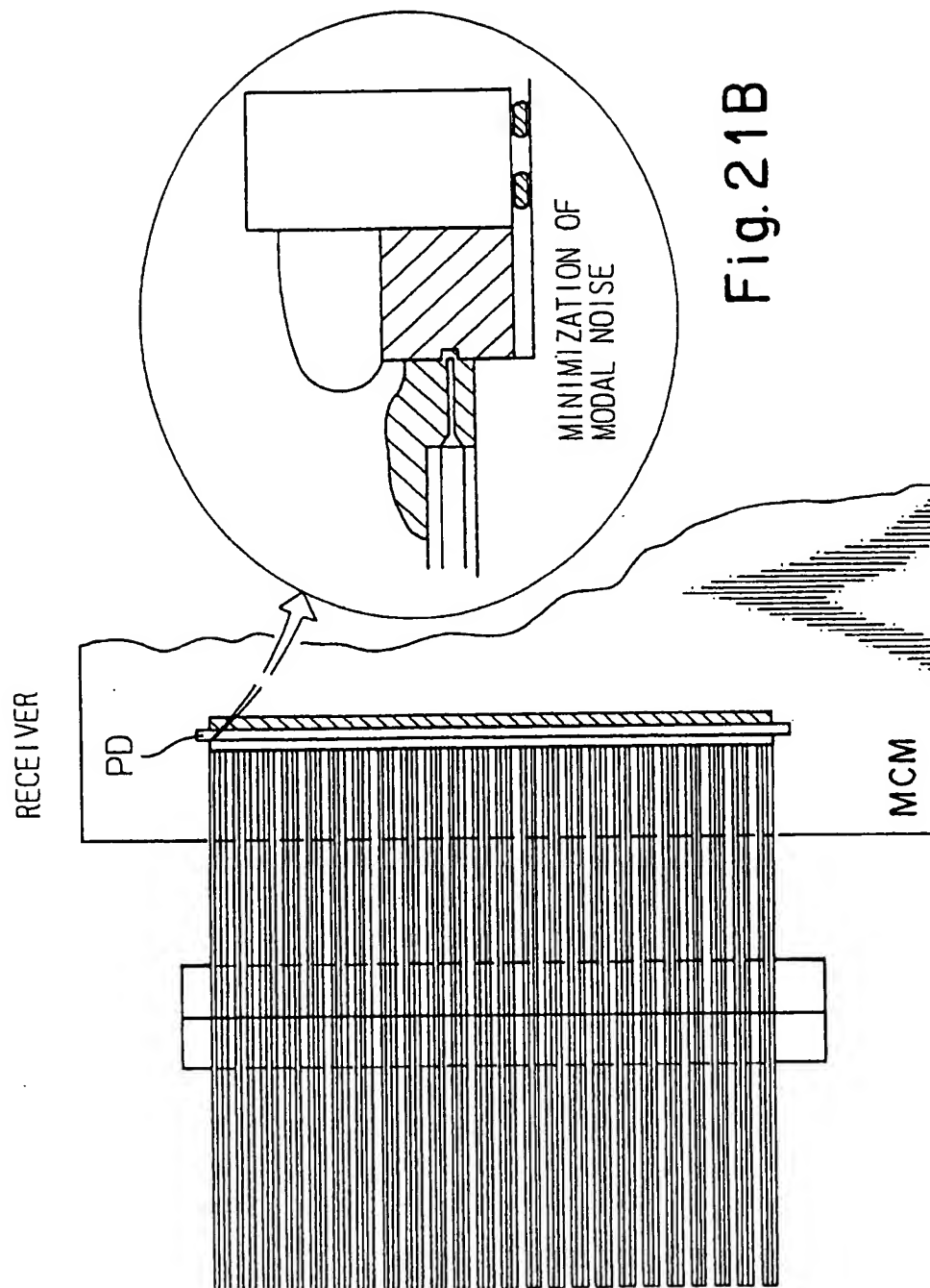


Fig. 21B

Fig. 22(a)

OPTICAL WIRING BY SIMPLE PLACEMENT OF PCB

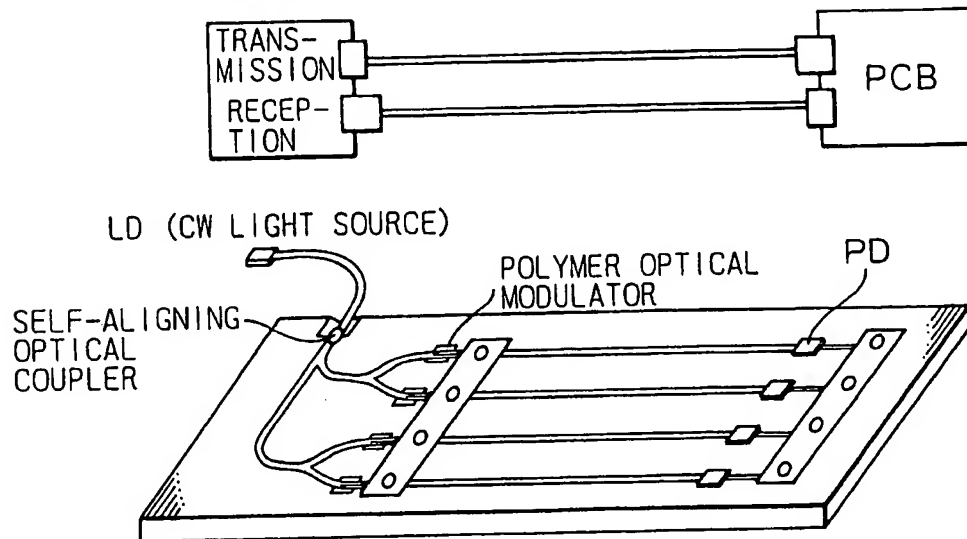


Fig. 22(b)

OPTICAL WIRING BY SIMPLE PLACEMENT OF PCB

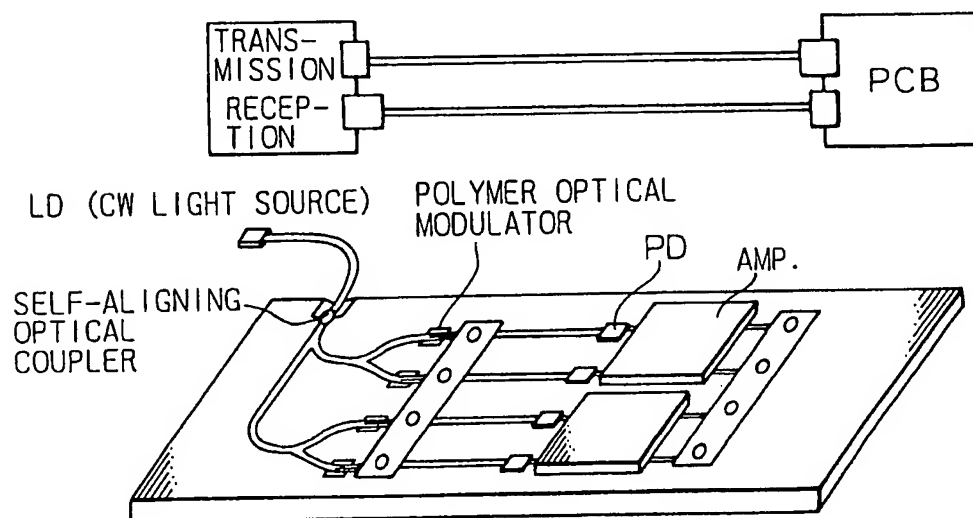


Fig. 23

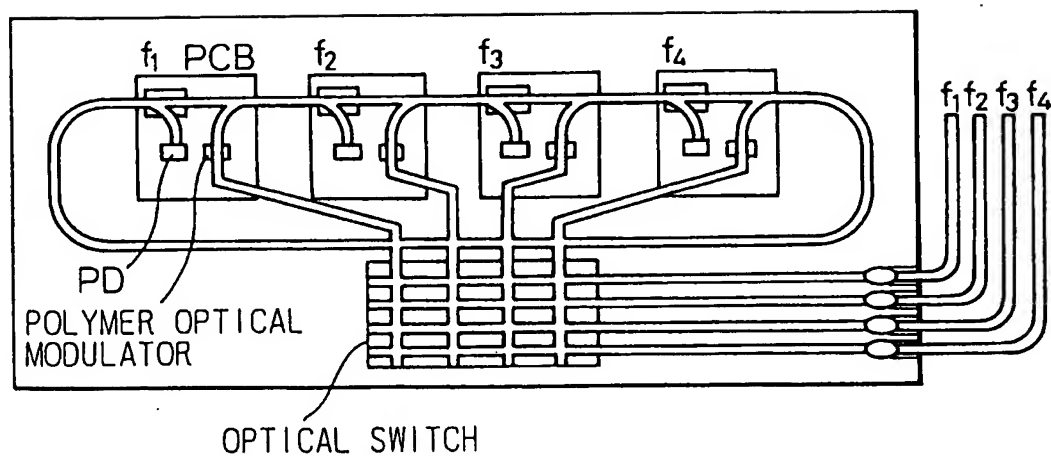


Fig. 24(c)

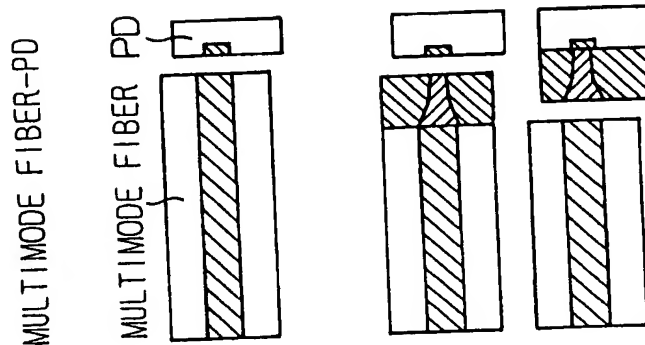


Fig. 24(b)

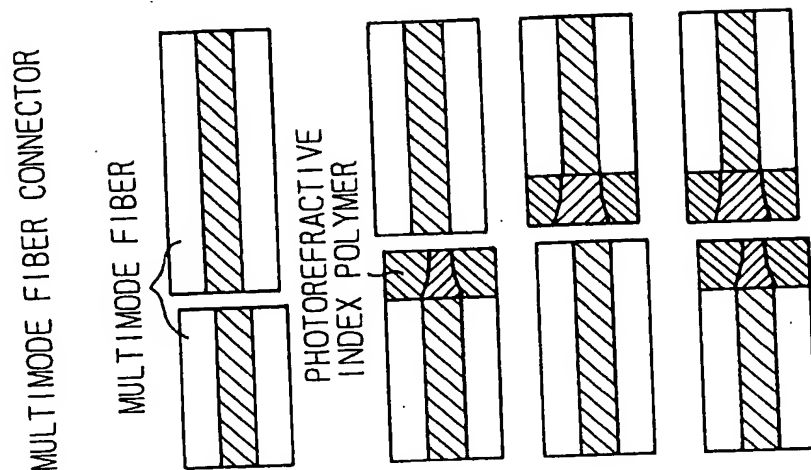


Fig. 24(a)

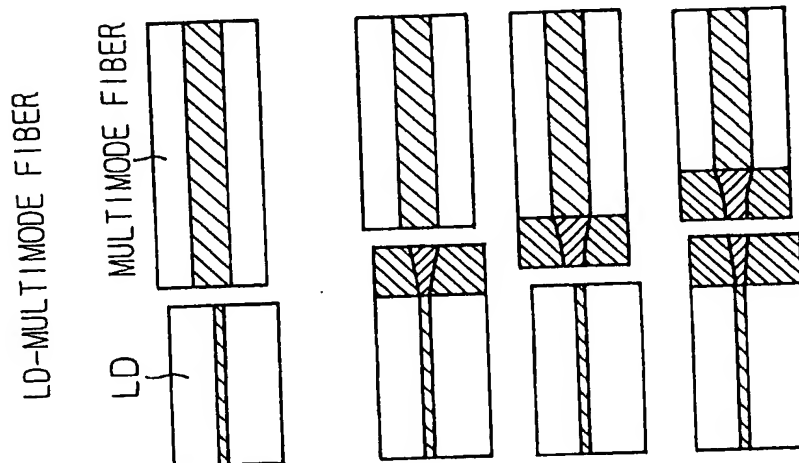


Fig. 25

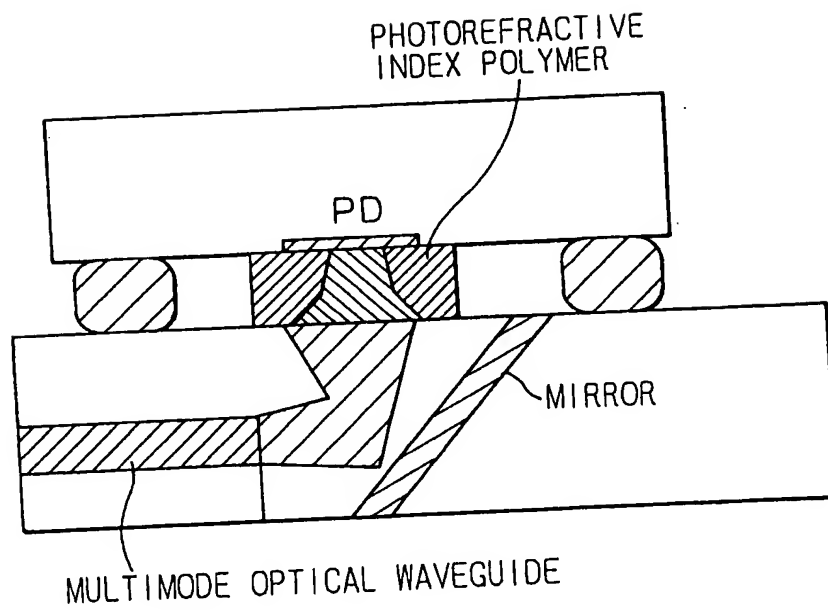


Fig. 26B

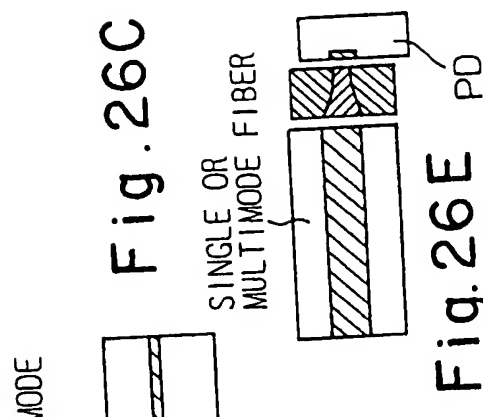


Fig. 26A

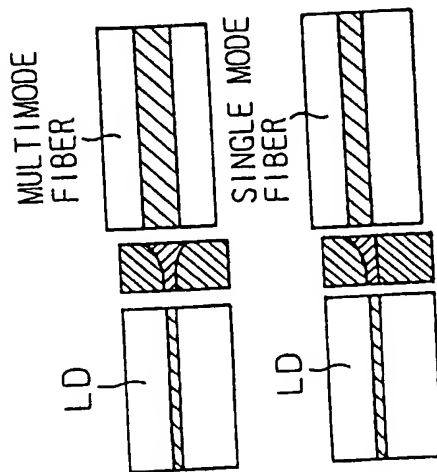


Fig. 26D

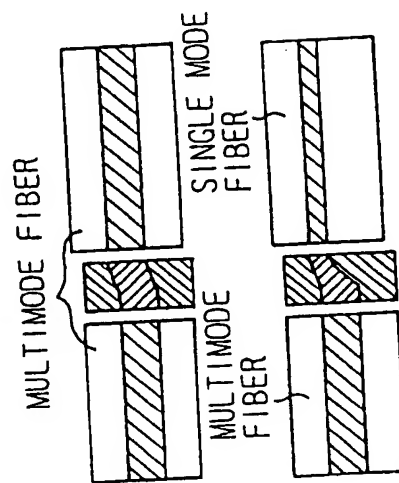


Fig. 26F

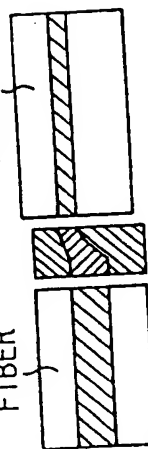


Fig. 27A

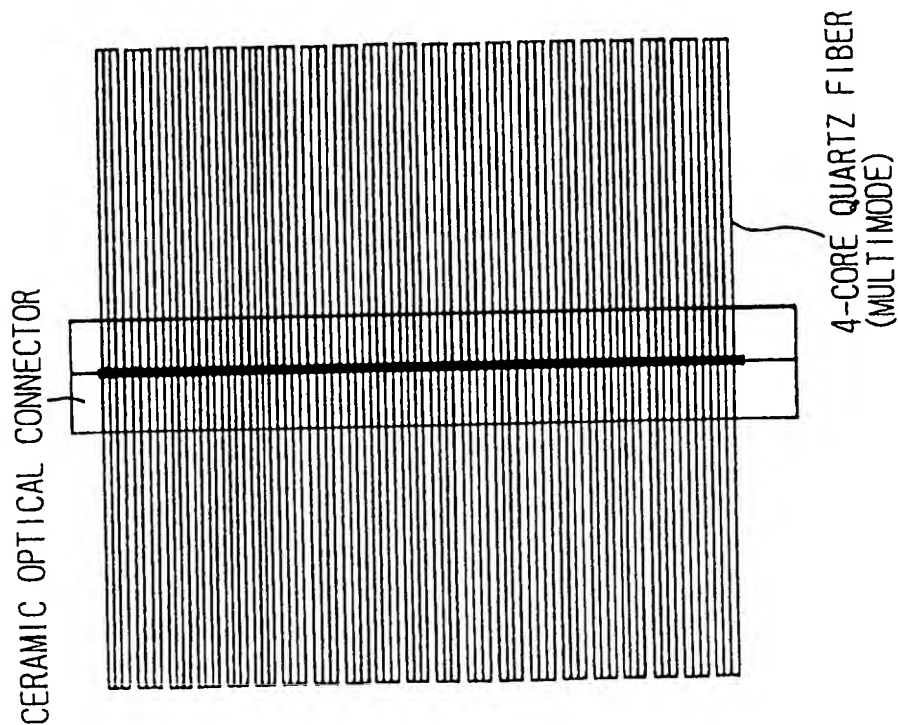


Fig. 27B

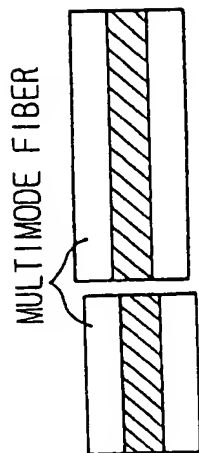


Fig. 27C

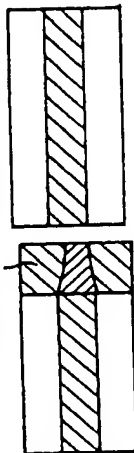


Fig. 27D

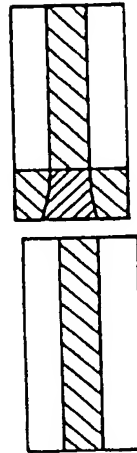
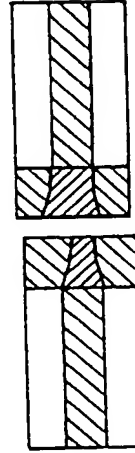


Fig. 27E



COUPLER MAGNIFIED

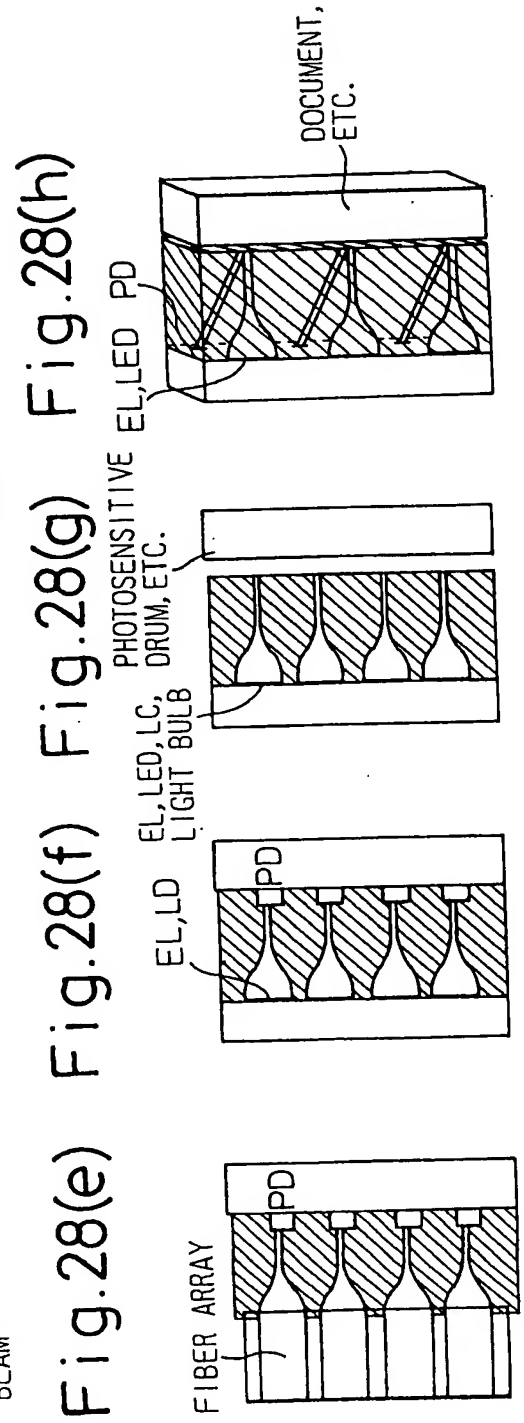
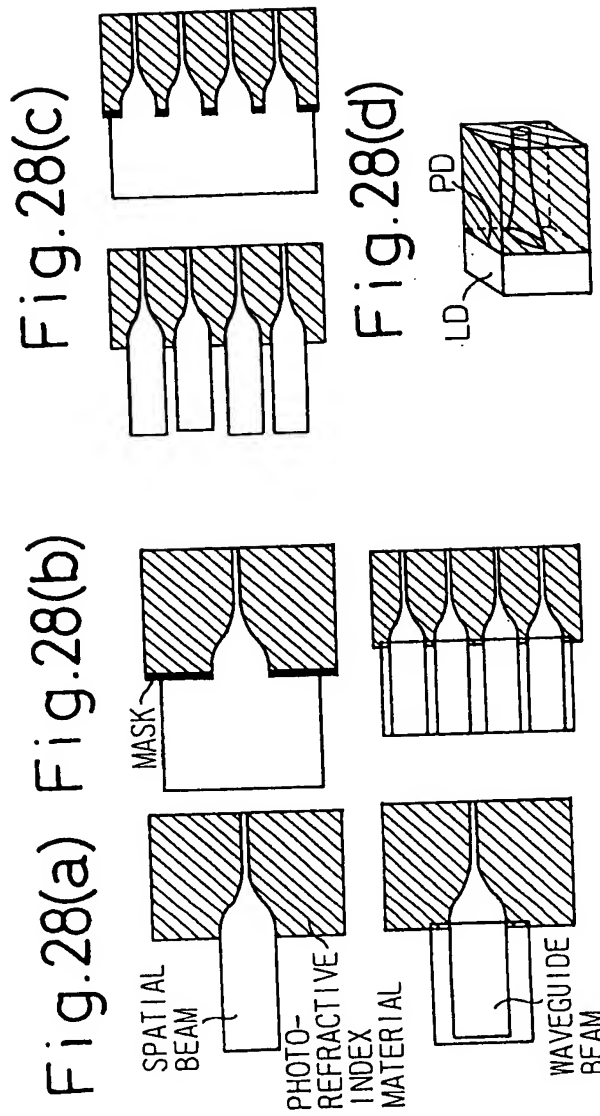


Fig. 29(a) Fig. 29(b) Fig. 29(c)

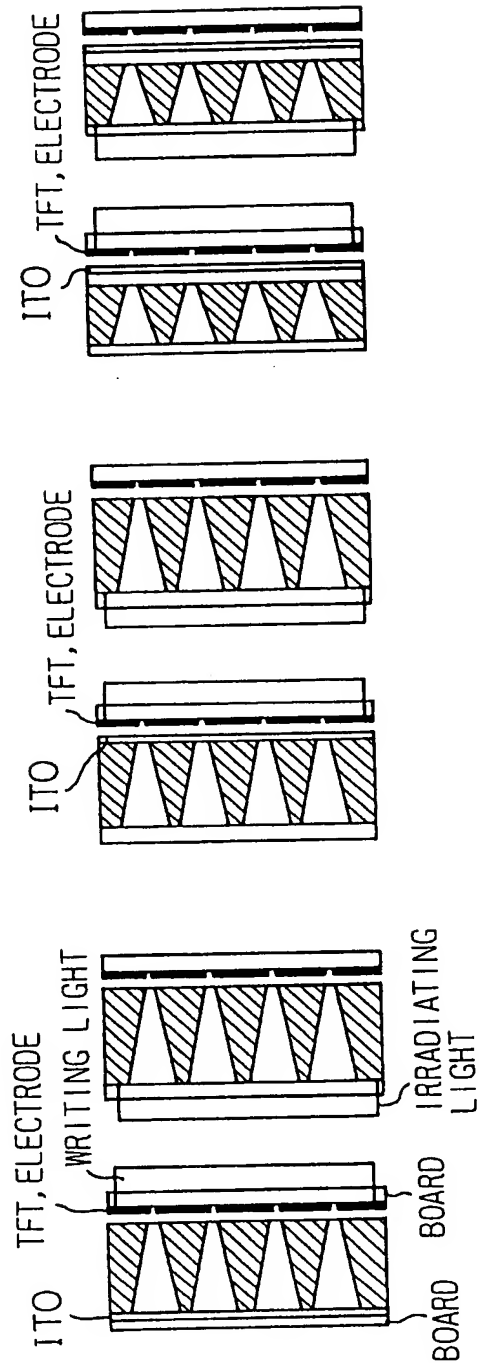


Fig. 29(d)

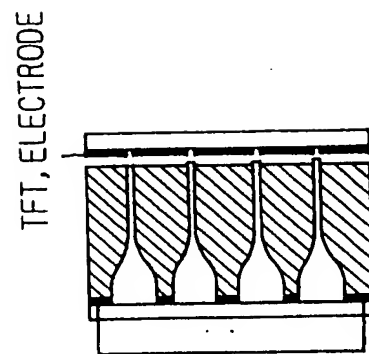


Fig. 30

OPTICAL KEY

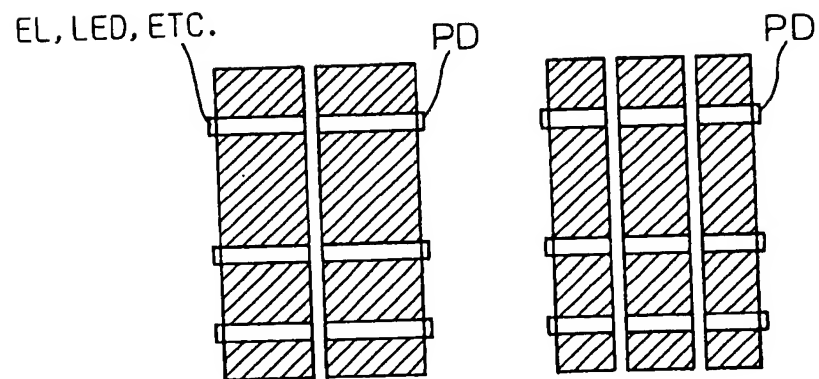


Fig. 31(c)

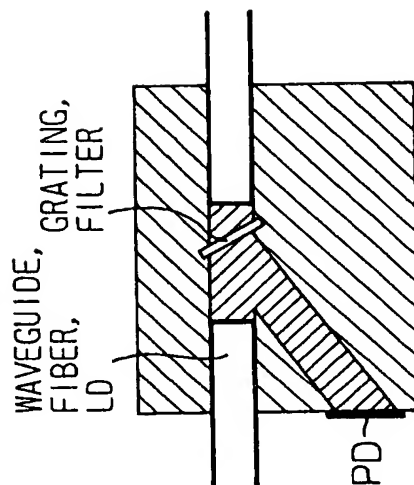


Fig. 31(b)

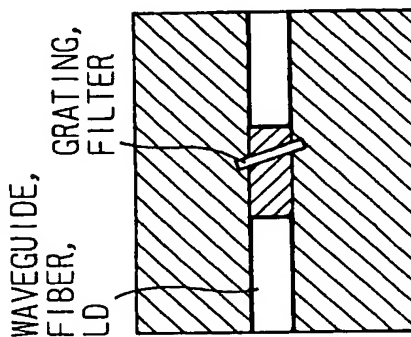


Fig. 31(a)

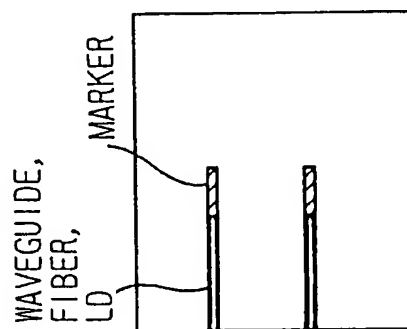


Fig. 32

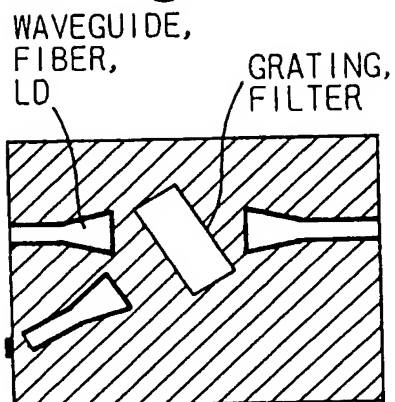
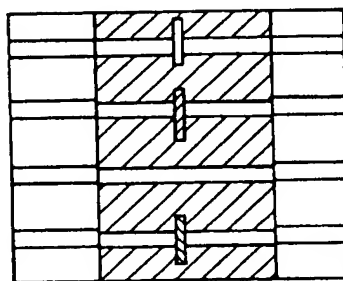
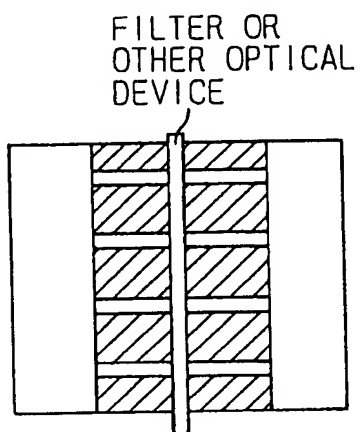


Fig. 33(a)

Fig. 33(b)



ACTIVE OPTICAL CIRCUIT SHEET OR ACTIVE OPTICAL CIRCUIT BOARD, ACTIVE OPTICAL CONNECTOR AND OPTICAL MCM, PROCESS FOR FABRICATING OPTICAL WAVEGUIDE, AND DEVICES OBTAINED THEREBY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to active optical circuit sheets and active optical circuit boards.

The present invention also relates to active optical connectors and optical MCMs. It further relates to wavelength multiplex active optical connectors and wavelength multiplex optical MCMs.

The present invention further relates to a process for fabricating optical waveguides and to devices obtained thereby.

2. Description of the Related Art

The increasing speed and miniaturization of LSIs has created serious problems which include wiring delays, heat buildup and generation of EMI within and between such electronic devices as IC boards, MCMs, back planes, LSIs, personal computers, workstations, computers, peripheral devices, terminals and the like. In light of this situation, many attempts have been made to introduce optical wiring into electronic devices.

The major optical wiring system employed is a direct modulation system wherein an LD or other light-emitting device is switched on and off; problems remain, however, in the high cost of LD arrays, the need for driving LSIs, the occurrence of skews, and the difficulty of optical axis alignment. Nevertheless, it is possible to achieve improvements over the above-mentioned problems by applying an external modulation system using an electrooptical modulator. Also, since the driving current for the optical modulator is smaller than that of the LD (because the optical modulator is voltage-driven), the EMI radiation may be further reduced. In light of this, a number of external modulation system LSI-connecting optical printed circuit boards have been proposed (for example, Fujitsu: Japanese Unexamined Patent Publication No. 63-229427, IBM: U.S. Pat. No. 4,422,088, Lockheed: U.S. Pat. No. 5,039,189 and GEC-Marconi: GB2240682A). However, because all of these have the electric wiring and optical wiring formed on a single board, the following problems arise, namely:

The production process for the circuit board becomes more complicated,

The cost is increased,

The wiring freedom is restricted, and

The soldering connection process for the LSI produces defects in the electrooptical modulator.

In addition, since, according to the prior art described above, the modulator array is formed directly under or near the LSI output terminal, the locations for optical signal generation are limited.

For optical wiring between electronic devices, there have been proposed optical wiring I/O adaptors also based on an external modulation system (Japanese Unexamined Patent Publication No. 63-229427). The aforementioned problems do not exist in this case, but even more freedom in optical wiring would be expected by realizing optical wiring which can be used both within and between electronic devices.

Furthermore, with conventional active optical connectors and optical MCMs, wherein light from a light source is

modulated by electrical output from an electronic device, circuit board, LSI or other electronic apparatuses to convert the outputted electrical signal to an optical signal which is then transmitted, and which are mounted onto the electronic devices, the light-emitting light source and the light incident section have become obstacles.

In addition, conventional optical multiplex wiring between electronic devices has required that each device be equipped with a wavelength-variable light source or multiple light sources with different wavelengths.

Moreover, the fields of data processing and communication have seen dramatic progress in the area of optical wiring, and the diffusion of optical technology such as optical parallel processors and "fiber to the home" is expected to continue in the future. Light-employing information-related devices, such as optical disks, POS systems, optical printers, image sensors, displays and the like are also becoming more common. Such devices are expected to require high performance, downsizing, lower cost and lower power consumption, while a variety of different types of optical-related apparatuses and devices will be developed. In light of these circumstances, as the need increases for various optical integrated circuits, including optical waveguide devices, and light control techniques as well, easy and efficient optical coupling between different optical devices such as optical fibers will become imperative.

However, this field of technology must deal with the following problems.

- (1) Known etching methods for forming waveguides have had low positioning precision and freedom of shape.
- (2) Though positioning precision has been attempted with the V-groove method, adequate performance has not yet been realized.
- (3) Optical connector loss and modal noise in multimode systems have been problems.
- (4) Optical elements sometimes cannot be easily detached.
- (5) Labor has been required for alignment of beams and lenses when employing lens arrays for adjusting waveguide beams and spatial beams for shape variation.
- (6) There has been no method allowing easy reconstruction of light which varies in diameter in the axial direction (e.g. to approach a circle).
- (7) There has been no method for automatically and readily forming the optical paths of optical wiring.
- (8) With optical printers, there has been no method for automatically and readily forming optical paths guiding light to photosensitive drums.
- (9) With image-reading devices, there has been no method for automatically and readily forming optical paths coupling the light sources, the objects to be read and the PDs.
- (10) With TFT-driven liquid crystal displays, there has been no method for automatically guiding light to TFT openings.
- (11) No keys have been provided which are recognized by waveguide orientation.
- (12) There has been no method for forming a marker with light emitted from the waveguide end after formation of the waveguide.
- (13) There has been no method for easily inserting optical devices midway through waveguides.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome the aforementioned problems of external modulation system

optical wiring, by providing an active optical circuit sheet and active optical circuit board wherein the optical wiring section is separate and independent of the optical/electrical hybrid board, and the optical wiring section and electrical wiring section can be very freely and easily incorporated.

In particular, the object of the present invention is to provide an active optical circuit sheet and active optical circuit board having a construction which allows optical signals to be generated by probing especially at desired locations of voltage generation on pads, terminals, wiring, etc. of electronic devices.

It is another object of the present invention to eliminate mounting obstacles for active optical connectors or optical MCMs caused by the presence of light sources or light incidence sections.

It is yet another object of the present invention to eliminate the need for orienting wavelength-variable light sources or multiple light sources of different wavelengths in different electronic devices of wavelength multiplex active optical connectors or wavelength multiplex optical MCMs.

Another of the aims of the present invention is that of overcoming the aforementioned problems (1) through (13) by using photorefractive index materials and employing a light self-focusing effect, in order to realize optical integrated circuits and optical control techniques through simple and highly efficient optical coupling between optical devices.

In order to achieve the objects, the present invention provides an active optical circuit sheet or active optical circuit board as an optical circuit board wherein an electrooptical switch or optical modulator built on a board is driven with a voltage (SIGin) from an electronic device (an IC board, MCM, back plane, LSI, personal computer, workstation, computer, peripheral device, terminal or the like), the electrical signal (SIGin) is converted to an optical signal by pick-up or modulation of at least a portion of the light from a waveguide or light source on the board, the optical signal is transmitted through a waveguide and/or optical fibers and converted to an electrical signal (SIGout) by a photoreceptor element built into or mounted on said board or another board, or a photoreceptor element provided on an LSI, and the signal is transmitted to another electronic device or the same electronic device, characterized in that an electrical connection is formed between the optical wiring board and the electronic device, separating the electrical wiring at the electronic device end and the optical wiring at the optical wiring board end, or SIGin and SIGout electrode pads are also provided on the side of the optical wiring board on which the optical device is mounted or the opposite side, for connection with the electronic device.

The present invention further provides an active optical connector or optical MCM which modulates light from a light source based on electrical output from an electrical apparatus such as an electronic device, circuit board or LSI, converts the outputted electrical signal to an optical signal and optically transmits it, characterized in that light is directed incident to the active optical connector or optical MCM at an angle which is not parallel to the optically transmitted output, or in the direction opposite to the optically transmitted output.

The present invention further provides an active optical connector or optical MCM which modulates light from a light source based on electrical output from an electrical apparatus such as an electronic device, circuit board or LSI, and converts and optically transmits the outputted electrical signal as an optical signal, characterized in that light is supplied from a unit at the optical signal receiving end.

The present invention further provides a wavelength multiplex active optical connector or wavelength multiplex optical MCM characterized in that light of different wavelengths is supplied, and switching of the different light is performed with a matrix optical switch or matrix optical filter to supply light of given wavelengths to optical modulators corresponding to given electronic devices.

The present invention further provides an optical connector comprising optical coupling paths in either or both directions between optical devices, formed by situating a photorefractive index material between all or some of a plurality of optical devices and irradiating light from one or more of the optical devices to create a refractive index distribution in the optical photorefractive index material, characterized in that at least one of the plurality of optical devices is detachable.

The present invention further provides a process for fabricating an optical waveguide, characterized by directing spatial propagated light, waveguide light or radiated light on a photorefractive index material to form a refractive index distribution while producing a self-focusing effect.

The present invention further provides,

optical wiring characterized in that radiated light from a device selected from optical fibers, optical waveguides, semiconductor lasers, light-emitting diodes, EL elements, spatial optical modulator elements, lenses, holograms, prisms, gratings, mirrors, pinholes, slits and filters, and arrays thereof, is directed incident to a photorefractive index material either connected to or spaced from the device to form a refractive index distribution, while producing a self-focusing effect, and the terminal thereof is formed by connection to or spacing from a photodiode array;

an optical printer characterized in that radiated light from a device selected from optical fibers, optical waveguides, semiconductor lasers, light-emitting diodes, EL elements, spatial optical modulator elements, lenses, holograms, prisms, gratings, mirrors, pinholes, slits and filters, and arrays thereof, is directed incident to a photorefractive index material either connected to or spaced from the device, while producing a self-focusing effect, to form a waveguide with a diameter smaller or equal to the incident end, and the terminal thereof is formed by connection to or spacing from a photosensitive drum or photosensor;

an image reading device characterized in that radiated light from a device selected from optical fibers, optical waveguides, semiconductor lasers, light-emitting diodes, EL elements, spatial optical modulator elements, lenses, holograms, prisms, gratings, mirrors, pinholes, slits and filters, and arrays thereof, is directed incident to a photorefractive index material either connected to or spaced from the device, while producing a self-focusing effect, and the light is reflected with a light reflector positioned near the edge to form a bent waveguide with a diameter smaller or equal to the incident end, wherein the terminal thereof is formed by connection to or spacing from a photodiode PD;

an LCD display characterized in that a photorefractive index material is positioned on a TFT-formed board or a board facing it in a TFT-driven liquid crystal display, light is irradiated from the side of the board on which the TFT is formed, and a refractive index distribution is formed in the photorefractive index material by light passing through an opening;

an optical key characterized in that radiated light from a device selected from optical fibers, optical waveguides,

semiconductor lasers, light-emitting diodes, EL elements, spatial optical modulator elements, lenses, holograms, prisms, gratings, mirrors, pinholes, slits and filters, and arrays thereof, is directed incident to a photorefractive index material either connected to or spaced from the device, while producing a self-focusing effect, to form a waveguide with a smaller or equal diameter as the incident end, and the terminal thereof is formed by connection to or spacing from a photodiode array, wherein at least one break is provided along the optical wiring;

a process for forming a marker, characterized in that a photorefractive index material is positioned on a region including an edge of a formed waveguide, and a marker is formed by light emitted from the waveguide;

a process for fabricating an optical circuit device, characterized in that a plurality of optical devices are formed or positioned, before, during or after which other optical devices are formed along the optical path between them, before, during or after which a photorefractive index material is positioned and light is emitted from at least one of the optical devices to form a waveguide; and

a process for fabricating an optical circuit device, characterized in that one optical device is formed or positioned, before, during or after which another optical device is formed, before, during or after which a photorefractive index material is positioned and light is emitted from at least one of the optical devices to form a waveguide.

The photorefractive index material refers to a material that changes its refractive index or solubility by light exposure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1(a)–1(d) are conceptual drawings of light transmission according to the invention.

FIGS. 2(a) and 2(b) are conceptual drawings of light transmission according to the invention.

FIG. 3 is a schematic view of an embodiment of conventional electrical wiring of a personal computer.

FIG. 4 is an illustration of an embodiment wherein printed circuit boards and an interface cable are optically wired with an active optical circuit sheet.

FIG. 5 is an illustration of an embodiment wherein an active optical circuit sheet is mounted on a printed circuit board.

FIGS. 6(a) and 6(b) are illustrations of embodiments of active optical circuit sheets or boards.

FIGS. 7(a) and 7(b) are illustrations of other embodiments of active optical circuit sheets or boards.

FIGS. 8(a) and 8(b) are illustrations of transmitter sections of active optical circuit sheets or boards.

FIGS. 9(a) and 9(b) are illustrations of receiver sections of active optical circuit sheets or boards.

FIGS. 10(a), 10(b), 10(c) and 10(d) are illustrations of embodiments showing the detailed structure of active optical circuit sheets or boards.

FIGS. 11(a), 11(b), 11(c) and 11(d) are illustrations of other embodiments showing the detailed structure of active optical circuit sheets or boards.

FIG. 12 is an illustration of an embodiment showing the connection structure between an active optical circuit sheet or board and a printed circuit board.

FIGS. 13(a)–13(c) are schematic views of an embodiment of an active optical connector for an optical parallel link module.

FIGS. 14(a) and 14(b) are schematic views of an embodiment of a bump junction between an optical modulator and an MCM terminal.

FIGS. 15(a)–15(c) are schematic views of another embodiment of an active optical connector for an optical parallel link module.

FIGS. 16(a) and 16(b) are schematic views of an applied embodiment of light transmission between computers with an active optical connector.

FIGS. 17(a) and 17(b) are schematic views of an applied embodiment of an active optical connector for a personal computer.

FIGS. 18(a)–18(c) are schematic views of an embodiment of an optical MCM/back plane.

FIGS. 19(a) and 19(b) are drawings of embodiments of materials for optical MCMs and active optical connectors, etc.

FIG. 20 is a schematic drawing showing the detailed structure of the EO transmitter section of the apparatus in FIG. 19.

FIGS. 21(a) and 21(b) are schematic drawings showing the detailed structure of the receiver section of the apparatus in FIG. 19.

FIGS. 22(a) and 22(b) are schematic views of embodiments of optical parallel back planes.

FIG. 23 is a schematic drawing of an embodiment of an optical MCM or optical back plane employing wavelength multiplex transmission.

FIGS. 24(a), 24(b) and 24(c) are schematic drawings of embodiments of optical fiber connectors.

FIG. 25 is a schematic drawing of another embodiment of an optical waveguide and PD coupling.

FIGS. 26(a) to 26(f) are schematic drawings of various embodiments of optical connectors.

FIGS. 27(a) to 27(e) are schematic drawings showing an embodiment of the detailed structure of the connector section between multimode fibers.

FIGS. 28(a), 28(b), 28(c), 28(d), 28(e), 28(f), 28(g) and 28(h) are schematic drawings of embodiments employing optical waveguides obtained by directing spatial propagated light, waveguide light or radiated light incident to a photorefractive index material to form a refractive index distribution.

FIGS. 29(a), 29(b), 29(c) and 29(d) are schematic drawings of embodiments of LCD displays wherein a refractive index distribution is formed in a photorefractive index material positioned on a TFT-formed board or a board facing it in a TFT-driven liquid crystal display.

FIG. 30 is a schematic view of an embodiment of an optical key.

FIGS. 31(a), 31(b) and 31(c) are schematic views illustrating a process for fabricating an optical circuit device.

FIG. 32 is a schematic view of an embodiment of a branching optical circuit.

FIGS. 33(a) and 33(b) are schematic view illustrating a process for fabricating a wavelength control device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be explained with reference to the attached drawings.

FIGS. 1(a) to 2(b) are conceptual drawings of light transmission according to the invention. FIGS. 1(a)–1(d) show a single channel case, and FIGS. 2(a) and 2(b) show a multichannel case. By contacting the electrode of an optical modulator with the electrode of an electrical circuit board, an optical signal is transmitted by the electrical output signals from the electrical circuit board. The optical signal is converted by PD into an electrical signal, and the signal is input to the electrical circuit board. Thus, very simple optical connections become available.

FIG. 3 is a schematic view of conventional electrical wiring using a personal computer as an example. Such devices require high speed and low power, particularly in long wiring for printed circuit board clocks, LCD-driving printed circuit boards, printed circuit board wiring, interface cables, and the like. These parts are also the major source of EMI. Optical embodiments of these parts are explained below.

FIG. 4 is an illustration of an embodiment wherein printed circuit boards and an interface cable are optically wired with a flexible active optical circuit sheet. This results in reduction in EMI. It also minimizes clock and data waveform corruption or degradation, and sometimes also the power required for signal transmission. The detailed structure of the active optical circuit sheet used here will be explained later, but this embodiment is constructed so as to allow optical connection of active optical circuit sheet pads to prescribed signal transmitting sections and receiving sections of the printed circuit board by simple establishment of electrical contacts. The signal transmitting and receiving sections do not necessarily require special pads, and the contacts may be established with normal wiring. In the case of optical interface cables, the edges of the optical circuit sheet become the optical connectors, as shown in the drawing.

FIG. 5 is an illustration of an embodiment wherein an active optical circuit sheet is mounted on a printed circuit board. Here, clock lines and other wiring for long distance transmission of high-speed pulses, are replaced with optical wiring. This results in reduction in EMI. It also minimizes clock and data waveform corruption, and sometimes also the power required for signal transmission. The active optical circuit sheet may be flexible, or it may be a flat active optical circuit board. These contain holes in order to avoid mounting parts on the printed board. In the case of a flexible sheet, each of the mounting parts may be covered.

FIGS. 6 through 9 show embodiments of active optical circuit sheets or boards. FIGS. 10 and 11 show embodiments of their detailed structure. FIG. 12 is an illustration of an embodiment showing the connection structure between an active optical circuit sheet or board and a printed circuit board.

FIG. 10(a) is an embodiment of an optical transmitter on which is mounted an LD-semiconductor EA (Electro-Absorption) optical modulator integrated device. The optical modulator is coupled with a waveguide. The LD emits light from DC by a constant current flowing from a VLD pad. The DC light is switched on/off by the EA modulator in response to voltage from a SIGin, for transmission of optical signals. The modulator is not limited to being an EA modulator, and devices utilizing non-linear optical effects may also be used. FIG. 10(c) is an embodiment wherein an external DC light source is introduced to the waveguide from optical fibers, and modulated by a semiconductor optical modulator. In this case, since heat generated by the LD does not affect the active optical circuit sheet or board, thermal management is

facilitated. FIGS. 10(b) and 10(d) are embodiments of PDs mounted on optical receivers. Optical signals transmitted through the waveguide are received at the PD, and then outputted to the SIGout after amplification by an amp. A biasing voltage is not necessary for the PD if this is a solar battery type, but must be supplied in other cases, though it is omitted in the drawing. PDs which may be used include waveguide types and small-capacity MSM devices. Sufficiently strong light power will render the amplifier unnecessary, to allow further simplification.

FIGS. 11(a) and (c) are embodiments utilizing polymer optical modulators. The transmission principle for these cases is the same as in FIGS. 10(a) and (c). A polymer optical modulator is more easily coupled with the waveguide because it can be incorporated monolithically into the board. In addition, the lower dielectric constant is effective for high-speed and low-current driving. FIGS. 11(b) and (d) are embodiments with PDs mounted on the surface. These may be realized by forming mirrors on the waveguide section. FIG. 11(d) is an embodiment in which no amp is used, which is the most preferred embodiment. It is also possible to provide the GND electrode on the surface side and the modulator electrode on the internal layer side, or alternatively depending on the structure of the device, both electrodes may be formed on the same side.

FIG. 12 is an embodiment of connection between an active optical circuit sheet and a printed circuit board (applying also to large-surface-area LSIs, etc.). Solder bumps may be used for the connections, but they sometimes result in defects in the active optical circuit sheet. Still, electrical connections may be easily established using a conductive adhesive or crimp contacts. In the embodiments in FIGS. 10(a)–10(d) and 11(a)–11(d), SIGin and SIGout pads are provided on the back side. When these are provided on the surface, the mounted parts become obstacles, thus severely limiting the direction of mounting. Therefore, the positioning freedom on the printing board may be increased by providing them on the back side. The connections may be located anywhere on the printed board which carries a voltage, such as on the electrode wiring, in addition to the pads and terminals. This allows the voltage signal to be probed at any desired point, for conversion to an optical signal. Such a feature has never been possible with voltage-driven external modulator systems. Furthermore, alignment of the connections may be facilitated by increasing the size of the SIGin and SIGout pads. Wider bands usually require drastically reduced electrode areas for optical modulators and optical switches. The volume of the pads has been a problem when electrodes of conventional optical modulators and optical switches are on the same side as the connection pads, but since according to the invention the pads are placed on the back side, the pad volume is reduced. Consequently, even if the pad area is made larger than the electrode area of the optical modulator or optical switch, the effect on the band decrease is minimal. Furthermore, by spreading a solid GND or Vcc, a shielding effect may be obtained.

FIG. 6(a) shows an embodiment wherein light is introduced externally through fibers, branched at a waveguide, transmitted by an optical modulator array, and received by a PD array. This active optical circuit sheet or board is mainly used for flexible optical connection between printed circuit boards and the like. FIG. 6(b) shows an embodiment wherein light is branched at the LD, and electrical signals at prescribed locations on the printed circuit board are converted to optical signals, transmitted, and received at the PD array. This sheet or board is suitable for internal wiring of a printed circuit board or for wiring between printed wiring boards.

FIGS. 7(a) and 7(b) are embodiments wherein light is first modulated by a modulator at the base and then distributed, and these are suitable for clock distribution.

FIG. 8 is an embodiment of a transmitter wherein electrical signals at prescribed locations on the printed circuit board are converted to optical signals, transmitted, and outputted to an external fiber cable. Also, FIG. 9 is an embodiment of a receiver wherein the optical signals from an external fiber cable are converted to electrical signals at prescribed locations. These are based on the same concept as an optical wiring I/O adapter (Japanese Unexamined Patent Publication No. 63-229427), but with the novel aspect that the light is introduced into the interior of the printed board. This allows further shortening of the electrical wiring length.

Useful optical modulators and optical switches for the present invention include, for example, Mach-Zehnder types, directional coupling types, (full) reflective types, phase retardation types, electro-absorption types and digital optical switch types. Useful nonlinear optical materials include electrooptical polymers, conjugated polymers, nonlinear optical glass, semiconductors, and the like. Waveguide materials include polymers and glass. The entire waveguide need not be made of a nonlinear optical material, as only the switch portion may be made nonlinearly optical. In such cases, a passive waveguide made of fluorinated polyimide or glass may be used. The board may be glass, a Si wafer or a polymer. Polymer materials are particularly preferred when flexibility is a requirement. The thickness of the board is suitably on the order of 10–1000 μm , and typical examples of materials are polyimide, epoxy, silicone and acrylic polymers. Standard PDs are made of Si or compound semiconductors. Other promising possibilities include photodiodes, phototransistors and MSM detectors made of a-Si, poly-Si and conjugated polymers, which allow monolithic coupling with the board. The receiving element may be formed at the upper end or lower end of the waveguide, or midway through the waveguide, to absorb light from the waveguide. The PD may also be formed on an LSI board or printed circuit board to receive light.

The preceding explanation concerns embodiments of printed circuit boards (IC boards), but it may be applied in the same manner to other electronic devices (MCMs, back planes, LSIs, personal computers, workstations, computers, their peripheral devices, terminals, etc.).

Furthermore, although the present invention has been explained mainly with respect to optical modulators, depending on the case light-emitting elements such as LDs, LEDs and ELs may be mounted instead of optical modulators. Driving LSIs will be necessary in such cases. A SIGin is inputted to a driving LSI to effect ON/OFF switching of the light-emitting element. Though more complicated than using an optical modulator, light transmission is still possible.

FIGS. 13(a)–13(c) are schematic views of an embodiment of an active optical connector for an optical parallel link module. LD light as CW light source is introduced from the side of the board, and then branched and guided to optical modulators. Each of the optical modulators is electrically connected to the output terminal of an electronic device (a processor element in this case) by, for example, an electrical connector or bump junction. Thus, optical signals corresponding to the electrical output are transmitted and sent to another processor element through, for example, an optical fiber. Since the light is supplied from the side, mounting is facilitated without obstruction by the light source. Mounting

is also made easier in cases such as shown in FIGS. 14(a)–(b) for example, where the optical modulator and MCM terminal are connected by bump junctions. FIGS. 14(a) and 14(b) show an embodiment of both a waveguide and PD material.

FIGS. 15(a) to 15(c) are schematic views of an embodiment wherein LD light as CW light source is introduced from the surface of the board (i.e. the direction opposite to that of light transmission) and is branched and guided to an optical modulator. Mounting is facilitated in this case as well.

FIGS. 16(a) and 16(b) are schematic views of an applied embodiment of light transmission between computers with a polymer active optical connector such as shown in FIGS. 13(a)–(c) or 14(a)–(b). FIGS. 17(a) and (b) show an applied embodiment of an active optical connector for a personal computer. The output from an IC card is converted to light for easier transmission. FIGS. 18(a)–18(c) are schematic views of an embodiment of an optical MCM/back plane. As mentioned above, an active optical connector is used for optical wiring inside the MCM or optical wiring to the outside of the MCM. For light transmission to the outside, it is effective from the standpoint of the mounting layout to direct the incident light at a nearly normal angle to the direction of light transmission.

FIG. 19 shows concrete embodiments of materials for optical MCMs and active optical connectors. The optical modulator used here may be an electrooptical polymer device, optosemiconductor device, LN (lithium niobate), or the like. The waveguide may be made of polymer or glass, but a optosemiconductor or LN may also be used. The amp is optional. FIG. 19(a) is an optically attached embodiment, and FIG. 19(b) is an electrically attached embodiment, both of which may have the construction described above.

FIG. 20 is a schematic drawing showing the detailed structure of the EO transmitter section of the optically attached type mentioned above. Incident light from the optical fibers is branched at polymer waveguides, and then modulated at an integrated electrooptical polymer optical modulator. The electrodes and pads have been omitted here. LDs may also be mounted instead of the optical fibers. FIGS. 21(a) and (b), on the other hand, are schematic drawings showing the detailed structure of the receiver section. Optical signals from an active optical connector such as shown in FIG. 20 are electrically converted by a PD or MSM detector. The amp is not necessary if the optical power is on the order of 1 mW, but in cases of low optical power an amp is essential. FIG. 22 shows embodiments of optical parallel back planes. In these cases, the optical wiring is completed simply by setting the printed circuit board (PCB). FIG. 22(a) is a case without an amp, and FIG. 22(b) is a case with a built-in amp.

FIG. 23 illustrates an embodiment of an optical MCM or optical back plane employing wavelength multiplex transmission. For example, light from f1, f2, f3 and f4 is introduced into waveguides and switched with a matrix optical switch (or optical filter). Assuming that wavelengths f1, f2, f3 and f4 have been assigned to PCBs 1, 2, 3 and 4, then when transmission from PCB1→PCB3, PCB2→PCB4, PCB3→PCB1 and PCB4→PCB2 is necessary, switching is accomplished to send f3 to PCB1, f4 to PCB2, f1 to PCB3 and f2 to PCB4. This allows simplification of the light source, improvement in wavelength stability and reduced LD cost and mounting costs.

FIG. 24 shows schematic views of some embodiments of fiber optical connectors. FIG. 24(a) illustrates an example of

LD/multimode fibers. A photorefractive index material is placed in all or part of the section between the LD/fibers, and light is irradiated from the fibers or LD, or both, to create a refractive index distribution in the photorefractive index material, forming an optical coupling path. The writing conditions are such that when writing from the LD a widened refractive index distribution is formed, and when writing from the fibers a refractive index distribution is formed by self-focusing. Writing is also possible from both ends with a SOLNET system (self-organized light waveguide network; see Japanese Patent Application No. 6-140502). Here, the photorefractive index material is adhered to either the LD end or the fiber end, or both, allowing easy detachment by leaving an area between them, etc. The same applies if the fibers are single-mode fibers. Furthermore, there is no correlation between the area left open and the reading end, and the two devices may be placed opposing each other as shown at the top row, with the writing accomplished from the fiber end (although the example in the top row is a case of writing from the LD end). With this orientation, writing from the fiber end forms a distribution such as, for example, shown in the middle row, even when the fibers and the photorefractive index material are apart. FIG. 24(b) shows an example of coupling between multimode fibers. The top row is a case of writing which employs self-focusing from the left, the middle row is a case of writing a widening refractive index distribution from the right (pulse writing), and the bottom row is a case where both of these are performed. In the case of the bottom row, the oriented photorefractive index material may be exposed at separate locations by both fibers. These methods provide reduction in modal noise with respect to light transmission from left to right. FIG. 24(c) shows fiber/PD coupling, wherein writing from the fibers is accomplished utilizing self-focusing.

As shown in FIG. 25, a mirror may be placed in the optical path, and the connector formed in the normal direction. Emission from the waveguide board writes a refractive index distribution into the photorefractive index polymer. In this drawing the emission from the board is tightened for strong self-focusing, but a weaker self-focusing effect may be used to guide the wave with roughly the same widening or to guide the wave while widening it.

The photorefractive index material used according to the invention may be a photopolymer prepared, for example, by adding a high refractive index carbazole to an acrylic binder or epoxy binder (polymer, oligomer or monomer), and further adding a sensitizing agent, polymerization initiator or the like. Such materials have an increased refractive index at light-irradiated portions. The sensitivity is normally between 400 and 700 nm. The written refractive index distribution may be fixed by heat, light irradiation, etc. It is also possible to reinforce the degree of cure and stability by UV irradiation or heat treatment. This of course in no way limits the material and other materials, such as polymer or glass, may be used so long as the refractive index varies with light irradiation. A sensitizing agent may also be added for long wavelength sensitization. As an example of LD light-absorbing substances there may be mentioned diphthalocyanine, polymethine, Kyasorb, IR-750, IRG-002, IRG-003, IR-820, IRG-022, IRG-023:CY-2, CY-4, CY-9 and CY20 (all trademarks of Nihon Kayaku, KK.).

FIGS. 26(a)–26(f) are schematic views of embodiments of various optical connectors. These are formed with a two-end writing SOLNET system (one-end writing for fiber/PD coupling). Here, the photorefractive index material stands apart from both devices. In this case, the material may

be formed into a plate and inserted between the devices. These embodiments may also be constructed so that the photorefractive index material is adhered to the devices, as shown in FIG. 24.

FIG. 27(a)–27(e) illustrate an embodiment of the detailed structure of the connector section between multimode fibers.

The device used is not limited to the one described above, and may be, for example, an optical waveguide, light-emitting diode, EL element, spatial optical modulator element, lens, hologram, prism, grating, mirror, pinhole, slit or filter.

FIG. 28 shows schematic views of embodiments employing optical waveguides obtained by directing spatial propagated light, waveguide light or radiated light incident to a photorefractive index material to form a refractive index distribution while producing a self-focusing effect. FIG. 28(a) is an embodiment wherein spatial propagated light, waveguide light or radiated light incident is directed incident to a photorefractive index material, and the beam is tightened by a self-focusing effect. FIG. 28(b) is an embodiment wherein a beam pattern is formed with a mask. FIG. 28(c) is an embodiment wherein an array of spatial beams are tightened. FIG. 28(d) is an embodiment wherein the diameter of the beam varies in the axial direction, and when the beam is not circular, a self-focusing effect is used to approximate a circular beam. For example, even if the beam diameter differs lengthwise and widthwise, the self-focusing effect may be used to approximate an equal diameter. FIG. 28(e) is an embodiment wherein light from a fiber array is tightened by a self-focusing effect and converged on PDs. It is thus possible to realize optical wiring by placing a photorefractive index material either in contact with or spaced from a device which is not limited to optical fibers but may also be selected from among optical waveguides, semiconductor lasers, light-emitting diodes, EL elements, spatial optical modulator elements, lenses, holograms, prisms, gratings, mirrors, pinholes, slits, filters, and arrays thereof, directing their emitted light to form a refractive index distribution while producing a self-focusing effect, and forming the terminal thereof by connection to or spacing from a photodiode array. FIG. 28(f) is an embodiment wherein light radiated from an EL or LD is converged. FIG. 28(g) is an embodiment of an optical printer wherein light from an EL element, LED (light-emitting diode), LC light bulb (spatial optical modulator element) or the like is converged and irradiated onto a photosensitive drum. The emitting light source is not limited to these, and may be selected from among optical fibers, optical waveguides, semiconductor lasers, lenses, holograms, prisms, gratings, mirrors, pinholes, slits, filters, and arrays thereof. The optical printer may be realized by placing a photorefractive index material either in contact with or spaced from the device, directing emitted light from the device, while producing a self-focusing effect, to form a waveguide with a smaller or equal diameter as the incident end, and forming the terminal thereof by connection to or spacing from a photosensitive drum or photosensor. FIG. 28(h) is an embodiment of an apparatus wherein light from an EL element or LED is converged, and first guided to a document surface, after which the reflected light is guided to a PD, for image reading. Instead of light from an EL element or LED, a device selected from among optical fibers, optical waveguides, semiconductor lasers, spatial optical modulator elements, lenses, holograms, prisms, gratings, mirrors, pinholes, slits, filters, and arrays thereof, may also be used. It is thus possible to realize an image reading device formed by placing a photorefractive index material either in contact

with or spaced from the device, directing emitted light from the device, while producing a self-focusing effect, and reflecting the light with a light reflector positioned near the edge, to form a bent waveguide with a smaller or equal diameter as the incident end, and forming the terminal thereof by connection to or spacing from a photodiode PD. This may be produced, for example, by placing the document on the mirror first and then exposing it to light.

In these embodiments, the wavelengths of the writing light and the light actually used may be the same or different.

The self-focusing effect makes possible a refractive index distribution with a smaller widening than the widening of the original light beam, and allows the waveguide to be formed with a smaller or equal diameter as the incident end, for effective focusing of the light.

The light may be spatial propagated light, waveguide light from an optical fiber, optical waveguide or semiconductor laser, or radiated light from a device selected from light-emitting diodes, EL elements, spatial optical modulator elements, lenses, holograms, prisms, gratings, mirrors, pinholes, slits and filters. Alternatively, a mirror, grating, hologram, prism, lens, waveguide, pinhole, slit or filter may be positioned over all or at least part of the region through which the light passes.

FIG. 29 is a schematic view of an embodiment wherein a photorefractive index material is positioned on a TFT-formed board or a board facing it in a TFT-driven liquid crystal display, light is irradiated from the side of the board on which the TFT is formed, and a refractive index distribution is formed in the photorefractive index material by light passing through an opening, to achieve effective use of light from a backlight or the like. These drawings omit the details of the oriented film. FIG. 29(a) is an embodiment wherein the photorefractive index material is positioned on the side of the opposing board on which the electrode is formed, and the writing light is irradiated from the TFT board side. The writing light passing through the opening forms a widened distribution in this case. As a result, a self-aligned converging path is formed in the opening, providing an increase in the panel brightness. FIGS. 29(b) and (c) are embodiments wherein the electrodes are formed after forming the photorefractive index layer. This allows more efficient use of the light without losing voltage efficiency to the liquid crystal layer. FIG. 29(d) is an embodiment wherein a converging path is formed by self-focusing from the opposing board side. In this case, writing light is also directed from the TFT board side, to effectively accomplish self-alignment in the openings in a SOLNET system.

FIG. 30 is an embodiment of an optical key. An EL, LED or the like is placed facing a PD or other receiver element in a prescribed orientation, and the optical path is written with light emitted from the light-emitting source. If one or more breaks are provided midway, with different break units, and light from the light source is directed onto all of the optical paths when they are later readjusted, then it is possible to determine whether each has the same setting. This may therefore be used as an identifiable key. It is not absolutely necessary for all of the units to be different, and they may be in a fixed block, for application in a variety of security management or pattern recognition devices. The light source may also be selected from among optical fibers, optical waveguides, semiconductor lasers, spatial optical modulator elements, lenses, holograms, prisms, gratings, mirrors, pinholes, slits, filters, and arrays thereof. It is thus possible to realize an optical key by forming a photorefractive index material either connected to or spaced from the light source,

and directing the emitted light incident thereto while producing a self-focusing effect, to form a waveguide with a smaller or equal diameter as the incident end, and forming the terminal thereof by connection to or spacing from a photodiode array, with at least one break being provided along the optical wiring. The waveguide may also have the breaks formed in advance and joined together.

FIG. 31(a) is a schematic view illustrating a process for forming markers, wherein a photorefractive index material is formed on a region including an edge of a formed waveguide, and a marker is formed by light emitted from the waveguide. This allows precise positioning of the emission core, and facilitates subsequent processes. FIG. 31(b) is a schematic view illustrating an embodiment of a process for fabricating an optical circuit device, wherein one or a plurality of optical devices are formed or positioned, before, during or after which other optical devices are formed along the optical path between them, before, during or after which a photorefractive index material is positioned and light is emitted from at least one of the optical devices to form a waveguide. Here, after the waveguide, etc. has been formed, the filter and the photorefractive index material which fills the area between them are positioned, after which a waveguide is formed from one end, or preferably both ends, of the waveguide by a SOLNET system. This allows insertion of the optical device into the optical circuit to be accomplished without the laborious conventional processes of cutting the waveguide and inserting the filter thereafter. An additional merit is that gaps between the filter and waveguide may be eliminated, and the filter may be fixed without modification. The case shown in FIG. 31(c) is similar, except that the light receiving structure has a branching PD. FIG. 32 illustrates an embodiment of a branched optical circuit. The optical devices for these embodiments are not limited to those mentioned above.

Furthermore, as shown in FIG. 33(a), a wavelength control device with waveguides on both sides (waveguide array) may be formed by positioning a photorefractive index material at both ends of, for example, a band pass filter, and irradiating a light beam thereon. Here, if the band pass filter is two-dimensional, a spatial device is formed, and if it is one-dimensional an array device or waveguide device is formed. A waveguide may also be formed by positioning a photorefractive index material between fibers or between waveguides (between a fiber array or between a waveguide array) at both ends of a band pass filter, and emitting writing light from both ends thereof. Here, the fibers or waveguides (fiber array or waveguide array) and the photorefractive index material may either be contacting or non-contacting. Conversely, the photorefractive index material may be positioned at opposite the ends of the fibers or waveguides (fiber array or waveguide array), and light writing accomplished either after or before inserting the band pass filter. The entire device may also be integrated. In FIG. 33(b) a plurality of devices are positioned between the fibers or waveguides. Such a device may be, for example, a band pass filter for different wavelengths.

As explained above, the present invention provides the following effects.

A. Formation of an active optical circuit sheet independent of the circuit board allows optical wiring to be introduced without complicating the production process for the circuit board.

B. Formation of an active optical circuit sheet independent of the circuit board allows optical wiring to be introduced without raising the cost.

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C. Formation of SIGin and SIGout pads on the back side makes possible optical wiring without hindrance by parts mounted on the active optical circuit sheet, and therefore without restricting wiring freedom from and to any desired location on the printed circuit board. In addition, the electrode (or pad) area for contacting an optical circuit board with an electrical circuit board can be enlarged without reducing the board width.

D. Formation of an active optical circuit sheet independent of the circuit board minimizes the influence of the LSI soldering connection process, thus preventing damage to the active optical circuit sheet. E. Formation of SIGin and SIGout pads on the back side makes possible optical wiring without hindrance by parts mounted on the active optical circuit sheet, to thus allow realization of freer optical wiring which can be used both within and between electronic devices.

F. Provision of an optical EMI noise source and formation of a solid GND or solid Vcc on the active optical circuit sheet results in lower EMI.

G. In addition: Light is directed incident to the active optical connector or optical MCM at an angle which is not parallel to the optically transmitted output, to eliminate obstacles when mounting. Light is supplied from a unit at the optical signal receiving end, to eliminate obstacles when mounting. Switching is performed with a matrix optical switch or matrix optical filter to supply light of given wavelengths to optical modulators corresponding to given electronic devices, thus eliminating the need to position a variable wavelength light source or multiple light sources of different wavelengths, for each electronic device. This makes it possible to realize low-cost, down-sized active optical connectors and optical MCMs with lower power consumption, as well as reduced skewing (compared to LD arrays), a lower failure rate, easier array formation, improved wavelength stability and improved power stability.

H. The present invention also provides solutions to the problems described below.

- (1) Known etching methods for forming waveguides have had low positioning precision and freedom of shape.
- (2) Though positioning precision has been attempted with the V-groove method, adequate performance has not yet been realized.
- (3) Optical connector loss and modal noise in multimode systems have been problems.
- (4) Optical elements sometimes cannot be easily detached.
- (5) Labor has been required for alignment of beams and lenses when employing lens arrays for adjusting waveguide beams and spatial beams for shape variation.
- (6) There has been no method allowing easy reconstruction of light which varies in diameter in the axial direction (e.g. to approach a circle).
- (7) There has been no method for automatically and readily forming the optical paths of optical wiring.
- (8) With optical printers, there has been no method for automatically and readily forming optical paths guiding light to photosensitive drums.
- (9) With image-reading devices, there has been no method for automatically and readily forming optical paths coupling the light sources, the objects to be read and the PDs.

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(10) With TFT-driven liquid crystal displays, there has been no method for automatically guiding light to TFT openings.

(11) No keys have been provided which are recognized by waveguide orientation.

(12) There has been no method for forming a marker with light emitted from the waveguide end after formation of the waveguide.

(13) There has been no method for easily inserting optical devices midway through waveguides.

We claim:

1. An optical circuit board, comprising:

a optical modulator regulating generation of light from a light source in correspondence with a voltage from an electronic device, and pick-up or modulation of at least a portion of light from an optical waveguide to produce an optical signal;

a photoreceptor element converting the optical signal into an electrical signal transmitted to the electronic device;

a waveguide connected between said optical modulator and said photoreceptor element transmitting the optical signal from said optical modulator to said photoreceptor element; and

an electrical connection formed between said optical circuit board and the electronic device, separating the electronic device from the optical circuit board at locations corresponding to said optical modulator and said photoreceptor element for providing the voltage from the electronic device to said optical modulator and for transferring the electrical signal output by said photoreceptor element to the electronic device.

2. An optical circuit board according to claim 1, wherein said electrical connection is provided by electrode pads disposed on an underside of the optical circuit board on which the optical circuit board is mounted for connection with the electronic device, the underside of the optical circuit board being opposite the side on which said optical modulator, said photoreceptor element, and said waveguide are disposed.

3. An optical circuit board, comprising:

a light-emitting device driven with a voltage from an electronic device to convert an electrical signal to an optical signal;

a photoreceptor element converting the optical signal into an electrical signal transmitted to the electronic device;

a waveguide connected between said light-emitting device and said photoreceptor element transmitting the optical signal from said light-emitting device to said photoreceptor element; and

an electrical connection formed between said optical circuit board and the electronic device, separating the electronic device from the optical circuit board at locations corresponding to said light-emitting element and said photoreceptor element for providing the voltage from the electronic device to said optical modulator and for transferring the electrical signal output by said photoreceptor element to the electronic device.

4. An optical circuit board according to claim 3, wherein said electrical connection is provided by electrode pads disposed on an underside of the optical circuit board on which the optical circuit board is mounted for connection with the electronic device, the underside of the optical circuit board being opposite the side on which said optical modulator, said photoreceptor element, and said waveguide are disposed.

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5. An optical circuit board according to claims 2 or 4, wherein the electrode pads on the optical circuit board are electrically connected to electrical wiring and terminals.

6. An optical circuit board according to claim 2, wherein an area of each of the electrode pads is wider than an area of an electrode directly in contact with the optical modulator.

7. An optical circuit board according to claims 1 or 3, wherein the optical circuit board is flexible.

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8. An optical circuit board according to claims 1 or 2, wherein the optical modulator is integrated with the optical circuit board.

9. An optical circuit board according to claims 1 or 2, wherein the optical modulator is made of at least one of a nonlinear optical polymer and a compound semiconductor.

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